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Aeronautical Engineering REVIEW

December, 1955

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Aeronautical Engineering REVIEW

Vol. 14—No. 12 December, 1955

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Cover—The Navy's giant jet seaplane, the Martin XP6M-1 SeaMaster, may usher in a new age for water-based aircraft. Designed for mine laying and photo reconnaissance, the SeaMaster flies 600 m.p.h. and carries a pay load of 30,000 lbs. Four Allison J71 turbojet engines, with afterburners for take-off, are mounted above the wings. The swept wings have a span of 100 ft. (See also article on page 26.)

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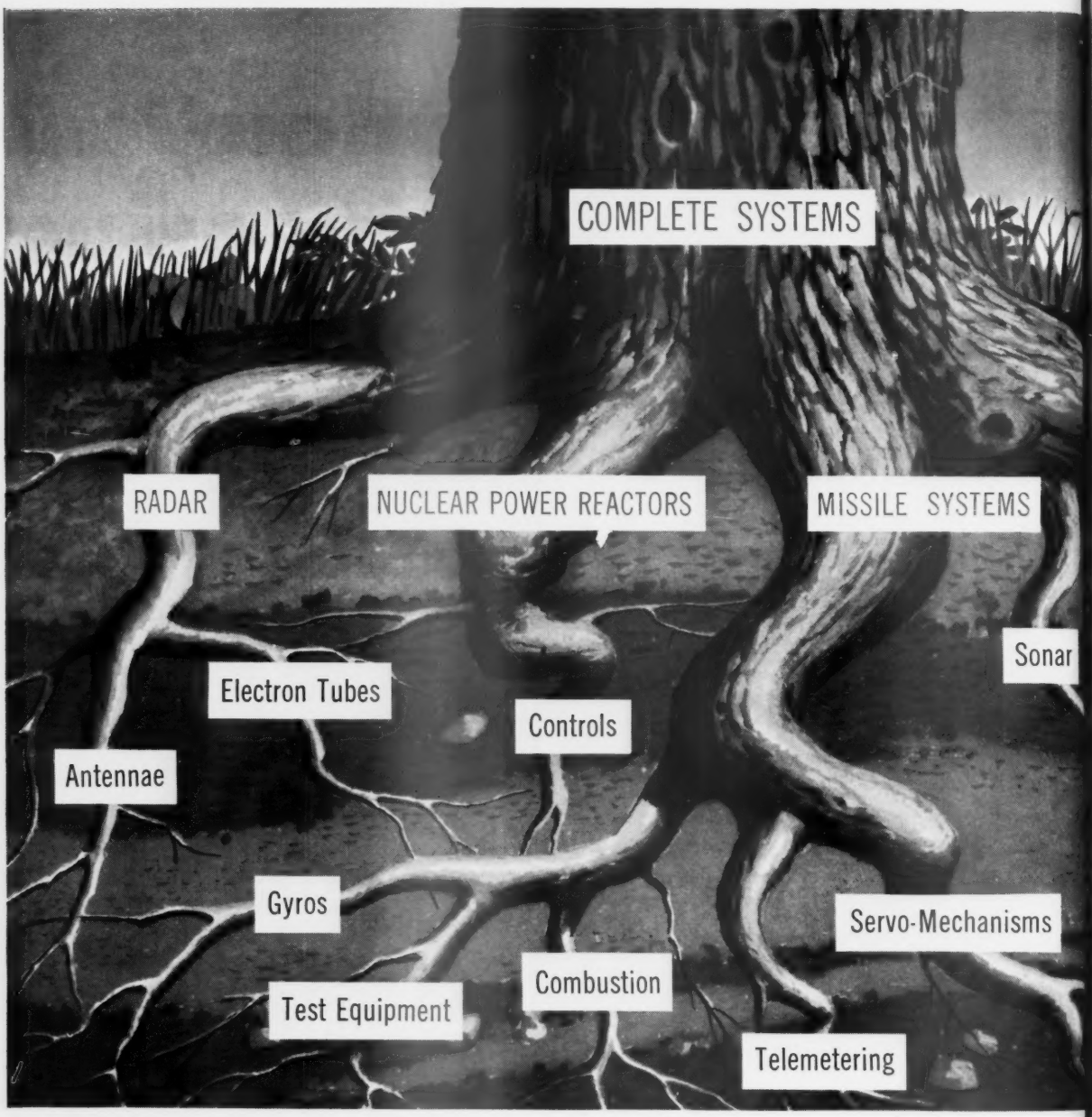

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I.A.S. News Notes

December 1955

INTERNATIONAL AERONAUTICAL ABSTRACTS. Beginning January, 1956, a new review of world-wide scientific and technical literature will appear under the support of the Air Force Office of Scientific Research of the Air Research and Development Command. Selected and prepared by the IAS staff, about 150 items will be included monthly from American and foreign sources. To make this service as current as possible, these abstracts will appear in a special "late bulletin" insert in each issue of the Aeronautical Engineering Review.

THE GUGGENHEIM MEDAL for 1955 will be presented to Theodore von Karman, Chairman of AGARD, at the Honors Night Dinner January 23. This year it was ASME's turn to make the presentation, but Dr. von Karman, who is living in Paris, was unable to attend the ASME Joint Honors Luncheon in Chicago November 17. The privilege of presenting the annual award rotates among ASME, SAE, and IAS.

TWO NEW SECTIONS of the Institute have been formed in Denver, Colorado, and San Antonio, Texas. The Colorado Section, headed by Major Vincent J. Bracha, USAF, plans to hold its dinner meetings in Denver, Colorado Springs, and Boulder. More than 100 attended the organization meeting of the San Antonio Section at Kelly AFB October 27. Sixteen companies and organizations were represented. The IAS now has 27 Sections.

ON DECEMBER 17 Hugh L. Dryden, an Honorary Fellow and Past President of the IAS, will receive the Wright Brothers Memorial Trophy and Richard T. Whitcomb, MIAS, will be given the Collier Trophy.

NATIONAL MEETINGS CALENDAR

Dec. 17	Nineteenth Wright Brothers Lecture, U. S. Chamber of Commerce Building Auditorium, Washington, D. C.
Dec. 19	Wright Brothers Lecture (Repeated), Benjamin Franklin Hotel, Seattle.
Dec. 20	Wright Brothers Lecture (Repeated), IAS Building, Los Angeles.
Dec. 22	Wright Brothers Lecture (Repeated), Lewis Flight Propulsion Laboratory, NACA, Cleveland.
Jan. 23-26	Twenty-Fourth Annual Meeting, Sheraton-Astor Hotel, New York.
Jan. 23	Honors Night Dinner, Sheraton-Astor Hotel, New York.
Mar. 9	Flight Propulsion Meeting (Confidential), Hotel Carter, Cleveland.
June 18-21	Summer Meeting, IAS Building, Los Angeles.

JOINT MEETINGS CALENDAR

Dec. 12-16	Nuclear Engineering and Science Congress (with Engineers Joint Council), Hotel Statler and Public Auditorium, Cleveland.
Mar. 14-16	ASME-SAE-IAS Air Cargo Sessions, Hotel Statler, Los Angeles.

* * * * *

I.A.S. News Notes (con't.)

SECTION MEETINGS CALENDAR

Dec. 1 Atlanta Section: Naval Air Station Officers Club, Chamblee, Ga. Reception 6:30 p.m., Dinner 7 p.m. "Weapons Systems: Their Philosophy and Development" by Lt. Col. R. C. Anderson, USAF, Chief, Research Div., Weapons Systems Directorate, ARDC.

Dec. 3 Los Angeles Section: Holiday Mixer (Dance) at IAS Bldg., 8:30 p.m.

Dec. 7 Chicago Section: Aircraft Engine Div., Ford Motor Co. Dinner 6:30 p.m., Technical Discussion and Tour of the Jet Engine Facility 7:30 p.m. Talk by A. C. Moore, General Manager.

Dec. 7 Philadelphia Section: Penn- Sherwood Hotel. Reception 6:30 p.m., Dinner 7 p.m., Meeting 8 p.m. "Problems Associated with the Fitting Out and Shaking Down of a Navy Attack Carrier" by Rear Adm. William A. Schoech, USN, BuAer.

Dec. 8 Dayton Section: Levitt's Manor. Reception 6: 30 p.m., Dinner 7 p.m.; Technical Discussion 8 p.m. "Naval Carrier Aircraft Operations and Special Equipment" by Capt. Willard M. Hanger, USN, BuAer.

Dec. 8 New York Section: Stratos Div., Fairchild Engine and Airplane Corp., Bay Shore, L. I. Tour of Stratos plant 5:30 p.m., Reception 6:15 p.m., Dinner 7 p.m., Meeting 8 p.m. "STOL Airplanes -- A New Approach to Transport Aircraft" by Robert A. Darby, Chief of Preliminary Design, Fairchild Aircraft Division.

Dec. 12 Indianapolis Section: B&B Restaurant. Reception 6 p.m., Dinner 6:45 p.m., Meeting 7:45 p.m. "Experience with the Viscount" by Hugh F. Jacox, Asst. Sales Promotion Manager, Capital Airlines.

Dec. 13 Los Angeles Section: Specialist Meeting at IAS Building, 8 p.m. "Inlets with External Boundary Layer" by John Seddon, British R.A.E.

Dec. 13 San Diego Section: Dinner Meeting at IAS Building, 7 p.m. "Principles of Engineering Organization" by Edgar Schmued, Vice-President (Engineering), Northrop Aircraft, Inc.

Dec. 14 Boston Section: Room 6-120, M.I.T. "Our Aeronautical Challenge -- Can We Meet It?" by H. Guyford Stever, Chief Scientist, USAF.

Dec. 15 St. Louis Section: Joint Meeting with American Helicopter Society, Engineers Club, 8 p.m. "Helicopters in Army Transportation" by Col. William B. Bunker, USA, Chief of the Transportation, Supply, and Maintenance Command.

Dec. 19 Seattle Section: Repetition of the Wright Brothers Lecture, Benjamin Franklin Hotel. Reception 6 p.m., Dinner 7 p.m., Meeting 8 p.m. "Some Structural and Aeroelastic Considerations of High-Speed Flight" by Prof. Raymond L. Bisplinghoff of M.I.T.

Dec. 20 Los Angeles Section: Repetition of the Wright Brothers Lecture by Prof. R. L. Bisplinghoff at IAS Building. Reception 6 p.m., Dinner 7 p.m., Meeting 8 p.m. (See topic above.)

Dec. 22 Cleveland-Akron Section: Repetition of the Wright Brothers Lecture by Prof. R. L. Bisplinghoff at Lewis Flight Propulsion Laboratory, NACA. Reception 6 p.m., Dinner 7 p.m., Meeting 8 p.m. (See above.)

Jan. 12 San Francisco Section: Ramor Oaks Restaurant, Atherton, Calif. Reception 6:30 p.m., Dinner 7 p.m., Meeting 8 p.m. Talk on activities of the General Dynamics Corp. by L.B. Richardson, Senior V-P.

* * * * *

IAS News

A Record of People and Events of Interest to Institute Members

The Twenty-Fourth Annual Meeting

Conference in New York Scheduled for January 23–26

J. R. Killian of M.I.T. to Address Honors Night Dinner

THE INSTITUTE OF THE AERONAUTICAL SCIENCES has scheduled its Twenty-Fourth Annual Meeting for January 23–26 at the Sheraton-Astor Hotel, New York. The Honors Night Dinner, as usual, will be held on the evening of the first day, Monday, January 23.

James R. Killian, Jr., President of Massachusetts Institute of Technology, will be the guest of honor and principal speaker at the Honors Night Dinner in the Astor's Grand Ballroom. The topic of his address will be "America's Capacity to Maintain Technological Leadership." This timely subject gains added significance from the fact that M.I.T. has trained many of the nation's noted aeronautical engineers.

Dr. Killian, who became President of M.I.T. 6 years ago at the age of 45, has placed an increasing emphasis on the humanities and social studies in the education of engineers and scientists. He favors more general education in the engineering curriculum. The first alumnus of M.I.T. to serve as President, Dr. Killian has been active in increasing the college's financial resources and in establishing a successful plan of industrial support for education and research.

Robert E. Gross, retiring President of the IAS, will be Toastmaster and will present the John Jeffries Award, Robert M. Losey Award, Sylvanus Albert Reed Award, and Lawrence Sperry Award. He will announce the election of Honorary Fellows and Fellows, both American and foreign, for 1955 and will introduce those who are present.

In addition to the dinner, luncheons with guest speakers are scheduled for Tuesday, Wednesday, and Thursday.

▶ The Institute's Annual Business Meeting, to which all members are invited, will be held Wednesday afternoon, January 25, at 5 o'clock in the North Ballroom. Reports on the previous year's activities and finances will be delivered at that time by the President, Treasurer, and Director. Vacancies on the IAS Council will be filled by election, and a Nominating Committee will be appointed for the coming year.

▶ For the first time in many years, no evening sessions will be held during the Annual Meeting. Instead, there will be more simultaneous sessions. Every morning, and every afternoon except the last, three sessions will be running at the same time. Approximately 88 papers will be presented during the 4 days of technical sessions. There are 23 different sessions scheduled.

Although the areas of research to be covered in the lectures will be much the same as in previous years, several new subjects will be added to the program. Chief among these are sessions on *Engineering Management Philosophies*, *VTO Aircraft*, *Earth Satellites*, and *Guided Missiles*.

Engineering Management Philosophies will be presented as a panel discussion.

Two sessions on electronics have been organized in cooperation with the Institute of Radio Engineers and the Radio Technical Commission for Aeronautics. One group of four papers will discuss *Improved Utilization of Air Space* by future jet transports and other high-speed aircraft flying at high altitudes. The other session, *Electronics and Aviation*, will cover more common topics such as cooling and packaging problems.

In the field of aircraft structures, there will be two separate sessions called *Thermal Stress Analysis* and *Failure of Structural Parts*. Another session will cover research in *Aeroelasticity*.

The *Aerodynamics* papers will be divided into three groups, including one session of four papers on *Hypersonic Aerodynamics*.

Internal flow problems involved in designing jet engines and air ducts for high-speed planes will be discussed in the *Flight Propulsion* session, which will be concerned mostly with the design of turbojet engines for supersonic aircraft.

James R. Killian, Jr.

In cooperation with the American Rocket Society, there will again be a session on *Rocket Propulsion*. Last year, the applications of JATO to aircraft occupied this spot in the program.

In two joint sessions with the American Helicopter Society, six papers will be read on *Rotating Wing Aircraft*.

The papers on *Meteorology*, as usual, will be presented in cooperation with the American Meteorological Society.

There will be separate sessions on *Air Transport* and *Aircraft Noise*, the latter sponsored jointly with the Acoustical Society of America.

Aircraft Design and *Aircraft Instruments* will appear on the program.

Flight Safety and Training will be the topic of a session arranged in cooperation with the Daniel and Florence Guggenheim Aviation Safety Center at Cornell University.

The Aeronautical Division of the American Society for Engineering Education will join in presenting a panel discussion on *Aeronautical Engineering Education*.

Last January, 1,500 members and guests registered during the 4-day meeting at the Sheraton-Astor.

Historic aircraft of pioneer days greet the visitor to Western Headquarters, Los Angeles, in this mural given to the IAS by The Liquidometer Corporation. A key identifies each subject. In the foreground are portrayed *(left to right)* Lt. H. H. Arnold, Lt. John H. Towers, Clarence A. deGiers, Glenn H. Curtiss, Capt. Thomas S. Baldwin, Frank T. Coffyn, Wilbur Wright, Orville Wright, Glenn L. Martin, Charles L. Lawrance, Octave Chanute, Grover C. Loening, Edson F. Gallaudet, George A. Page, Jr., Lt. Thomas E. Selfridge, Earle Ovington, and Robert J. Collier. Beside Collier is the Wright brothers' engine that powered their first flight.

Aviation Mural Presented to Western Headquarters

A conversation piece for visitors to IAS' Western Headquarters in Los Angeles is a handsome mural depicting some of the aircraft and some of the men that made aviation history. A page from da Vinci's notebook, sketches of early balloons and flying machines, and portraits of the daring aeronauts of yesteryear can be identified by a key chart posted nearby.

The mural was a gift to IAS from The Liquidometer Corporation, a Corporate Member of the Institute. How it came to be painted and how it found its way to the lounge in Western Headquarters is an interesting story.

In 1911 Clarence A. deGiers, MIAS, who is now President of The Liquidometer Corporation, was one of those aviation pioneers. He enrolled in the Moisant International Aviators School at Mineola Field, Long Island, N.Y., and learned to fly without benefit of copilot. When he left the ground in a Bleriot single-seater after a few practice runs across the bumpy field, he was on his own.

Obtaining F.A.I. License No. 77, deGiers went to Panama with the Moisant International Aviators and subsequently did some flying in Europe. He returned to the U.S. in 1914 to take a job as an instructor and test pilot.

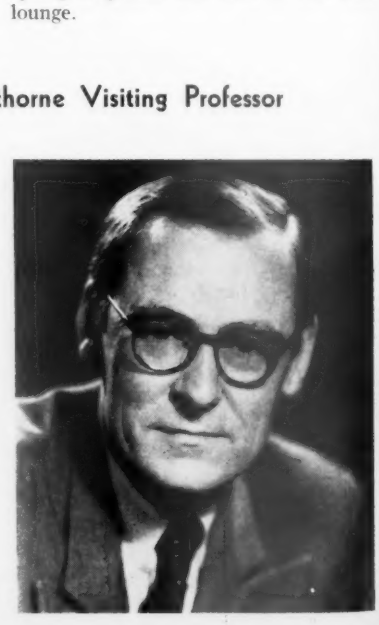
At the close of World War I, deGiers founded The Liquidometer Corporation to market some patents he had obtained on methods of measuring fuel in aircraft. Years later, he commissioned Justin C. Gruelle, an artist in Silvermine, Conn., to put on canvas the story of the growth of the principal industries that use his company's devices. Gruelle painted the aviation panel in 1940.

When deGiers became President of The Early Birds in 1953, he was active in erecting a monument to the aviation pioneers on Governors Island, in New York Harbor. At the dedication ceremony December 17, 1954, a company representative who was about to leave for California got into a chance conversation with an IAS official who urged him to "drop in" at the Western Headquarters. He did, and in the course of conversation with E. W. Robischon he happened to mention the historical painting.

Robischon, who is Manager of the Western Region of IAS, made it a point to visit Liquidometer's main office in Long Island City when he went to New York for the Annual Meeting last January. He saw the mural, and in his enthusiasm about its significance he pointed out that it should be exhibited in a more public place. The company offered it to IAS. A photomural was made to take the place of the original, and the canvas was shipped west. By spring it graced the wall of the IAS lounge.

M.I.T. Names Will Hawthorne Visiting Professor

William R. Hawthorne, MIAS, has been appointed to the new faculty post of Jerome Clarke Hunsaker Professor of Aeronautical Engineering at Massachusetts Institute of Technology for the current academic year.



On leave from Cambridge University, England, where he holds the Hopkinson and Imperial Chemical Industries Professorship of Applied Thermodynamics, Hawthorne is primarily interested in aircraft propulsion and advanced fluid mechanics. At M.I.T. he will divide his teaching efforts in these fields between the Departments of Mechanical and Aeronautical Engineering.

While at M.I.T. as Hunsaker Professor, he will deliver the Minta Martin Aeronautical Lecture. This may be repeated in other aeronautical centers

to emphasize the national character of the new professorship.

Hawthorne, who is a Fellow of the Royal Aeronautical Society, headed the Gas Turbine Division of the Royal Aircraft Establishment from 1940 to 1944. He has served on many English and American committees dealing with aircraft propulsion, fuels, and guided missiles. For 4 years he taught mechanical engineering at M.I.T. In 1950-1951 he was Chairman of the Boston Section of IAS.

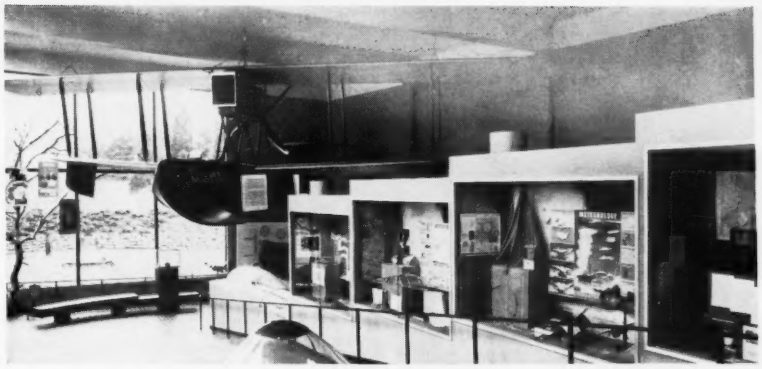
The professorship honoring Hunsaker, who headed M.I.T.'s Aeronautical Engineering Department for many years, is funded by gifts of over $360,000 from industry and individual donors. The idea was conceived and brought to realization largely through the initiative and efforts of Lester D. Gardner, an alumnus of M.I.T. and a founder of the IAS. Among other alumni on the fund-raising committee are James H. Doolittle, Donald W. Douglas, Luis de Florez, Leroy R. Grumman, Emory S. Land, and Edward P. Warner, all Fellows or Honorary Fellows of the IAS.

Hunsaker, an Honorary Fellow of IAS, is Chairman of the National Advisory Committee for Aeronautics.

Seattle Section Sponsors Aviation Exhibit in Museum

Institute members who attended the National Turbine-Powered Air Transportation Meeting last August had an opportunity to see the "Cavalcade of Aviation" in the Seattle Museum of History and Industry. Some also went to a television show staged there.

Engaging in a fine bit of public relations, the Seattle Section of IAS joined the Seattle Historical Society in sponsoring the exhibit. The Boeing Airplane Company and other manufacturers provided displays. So did the Air Force and Navy. The exhibit ran from June 5 until the end of October, and was reported to enjoy a large attendance.



One feature of the "Cavalcade of Aviation" exhibit in the Seattle Museum of History and Industry was an early mail plane, the Boeing B-1 flying boat. Its six-cylinder engine gave the two-seater a top speed of 93 m.p.h. Most of the major manufacturers, as well as the Air Force and Navy, provided displays.

The Cavalcade was the first aviation exhibit of its kind ever shown in Seattle. The displays included actual airplanes, model planes, working models and cutaway models of jet and piston engines, historical photos and documents, and other items tracing the history of aircraft and the aviation industry.

Among IAS members who took an active part in presenting the Cavalcade were Peter M. Bowers, leader of the Historical Associate Members in Seattle; Ben H. Carter, Jr., Alvin J. Jarvis, Jr., Philip Flash, Ned M. Thorne, Charles A. Bosserman, and Horace C. Pearman. All are with Boeing.

Apply Now for Fellowship in Flight-Test Engineering

The IAS is inviting applications for another 2-year Fellowship in Flight-Test Engineering at Princeton University. The winner, to be announced in March, will join several Navy and Air Force test pilots selected to pursue a specially designed program of graduate study there next fall.

Military and naval pilots attend at government expense, but the IAS Fellowship contributed by an anonymous donor is intended to provide for civilians. Three Fellowships have been given to date. Currently studying under the Fellowship are Warren J. North, 33, a former bomber pilot, flight instructor, and NACA research scientist, and William B. Browne, 27, a former jet fighter pilot who gained some industrial experience in summer jobs with aircraft companies.

Engineering students who will graduate next June and young men with a B.S. degree in any branch of engineering—preferably aeronautical engineering—are eligible for the Fellowship. They must be U.S. citizens. Applications may be submitted through Faculty Advisers or mailed directly to IAS headquarters in New York. Application forms have been distributed via IAS Sections and Student Branches.

Piasecki Establishes Plant

Frank N. Piasecki, FIAS, announced recently that Piasecki Aircraft Corporation has leased three buildings at Philadelphia International Airport and plans to construct others on an adjacent tract. Executive offices are located in the former airport post office. The other buildings were formerly used for air cargo and railway express. Vertical-lift aircraft will be designed and manufactured at this plant, Piasecki said.

The "Cavalcade of Aviation" sponsored by the IAS Seattle Section and the Seattle Historical Society presented full-scale airplanes, as well as numerous models, photos, engines, and pieces of equipment such as the rubber boat, with its radar reflector, shown here. The exhibit ran 5 months and was well attended.

Hyatt Honored by Navy for VTO Development

Abraham Hyatt, AFIAS, has received the Distinguished Civilian Service Award for his part in developing the Convair XFY "Pogo Stick" VTO fighter. James H. Smith, Jr., Assistant Secretary of the Navy for Air, made the presentation October 7. Hyatt is

Abraham Hyatt

Director of the Research Division of the Bureau of Aeronautics.

This award is the highest that the Secretary of the Navy can confer on a civilian employee. The citation read:

"For a successful original engineering approach to aircraft design and technological progress in aviation. His initiative, imagination, and engineering knowledge were responsible for opening a new engineering approach to the solution of highly important aircraft design and operational problems. His leadership and forcefulness resulted in formulation of a broad, comprehensive research and development program which is expected to produce significant changes in terms of performance and increased striking power of naval aircraft. His performance and resulting accomplishments reflect the highest credit on himself and the Department of the Navy, and fully merit the Distinguished Civilian Service Award."

In 1944 Major Hyatt, who was then in the Marine Corps, was cited by the Secretary of the Navy for his contributions to the development of two high-speed research airplanes, the Douglas D-558-I Skystreak and D-558-II Skyrocket. For his work on vertical-take-off fighters he was given the Navy League Award of Merit for 1954.

Frank R. Cook Organizes Electronic Equipment Firm

Frank R. Cook, AFIAS, has formed the Frank R. Cook Company, Inc., to engage in the design and manufacture of aeronautical and electronic equipment. With offices in Suite 600, Mile High Center, Denver 2, Colo., the firm has laboratory and manufacturing facilities in Denver and Colorado Springs.

Cook said the company will develop electronic equipment and automation components to meet the exacting requirements of supersonic and hypersonic flight conditions of aircraft and missiles, with emphasis on problems relating to the thermal barrier and all-attitude flight. The design program includes transistorized radio equipment of exceptionally light weight and low cost and an automatic battery for guided missiles. First production deliveries are scheduled next month.

Prior to forming his own company, Cook was Director of Research and Planning of the Aeronautical Division of Minneapolis-Honeywell Regulator Company. He is a former Member of the IAS Council.

An Air Force officer 17 years, rising to the rank of Colonel, he filled wartime assignments at Wright Field, in the Pacific, and in Korea. For two years he was Chief of the Research Division and the Plans Division of the Research and Development Directorate, Headquarters, USAF.

Frank R. Cook

NEWS OF MEMBERS

▸ **James H. Doolittle** (HF), Vice-President of Shell Oil Company, has been elected to Honorary Membership in The American Society of Mechanical Engineers.

▸ **Joel T. Henry** (M), President of Winder Aircraft Corporation, Lakeland, Fla., recently completed the senior officers' jet flying course at Moody AFB, Valdosta, Ga.

▸ **Arthur L. Hubbard** (TM), Department Engineer in charge of advanced electronic instrumentation and data analysis work at the Missile Systems Division of Lockheed Aircraft Corporation, has been selected by the company to attend a new 2-year "engineering executive" course offered by the University of California in Los Angeles.

Alexander Kartveli, FIAS, Vice-President and Chief Engineer of Republic Aviation Corporation, receives the honorary degree of Doctor of Engineering from Polytechnic Institute of Brooklyn in recognition of his design of the P-47 Thunderbolt, F-84 Thunderjet, and other military planes. He has been with Republic since 1931. Kartveli is shaking hands with Harry S. Rogers (*right*), President of Polytechnic Institute.

▸ **Peter F. Hurst** (M), President and General Manager of Aeroquip Corporation, has been elected to Tau Beta Pi.

▸ **William P. Lear** (AF), Board Chairman of Lear, Incorporated, has been elected to membership in Tau Beta Pi by Alpha Chapter of Michigan State College in recognition of his "outstanding record of achievement and integrity in the engineering profession."

▸ **Jerome Lederer** (F), Director of Flight Safety Foundation, Inc., has been elected a national Vice-President of the Air Mail Pioneers.

▸ **Frederick B. Lee** (M) was recently presented a certificate by the National Business Aircraft Association, Inc., "in recognition of his outstanding individual initiative and leadership as Federal Administrator of Civil Aeronautics, his far-sighted concept of industry problems, and his loyalty and devotion to the advancement of safety, navigation, and utilization of aircraft in all forms of transportation."

▸ **Roger Lewis** (AM) was awarded the Medal of Defense on September 30, his last day as Assistant Secretary of the Air Force (Materiel.)

▸ **Edward Warner** (HF), President of the Council, International Civil

Aviation Organization, has been honored by the French Government for "his outstanding work in civil aviation, particularly within the framework of ICAO." He was named a Commander of the Legion of Honor.

Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

Charles A. Barnett (M) has joined Fletcher Aviation Corporation, Pasadena, Calif., as Vice-President in charge of Engineering and Sales. He left Piasecki Helicopter Corporation to accept the position, and had previously been Vice-President and Chief Engineer of Kellett Aircraft Corporation.

W. H. Beardslee (M) has opened his own office as an engineering and sales representative to the aircraft industry at 441 North Griffith Park Drive, Burbank, Calif. He was formerly Sales Manager of the Missile-Aircraft Engineering Company, Sun Valley, Calif.

Arnold R. Beckhardt (M) has been promoted to Manager of the Flight Test Department at the Airborne Computer Laboratory of International Business Machines Corporation, Endicott, N.Y.

Pfc. David B. Benepe, USA, (M) has been appointed an Instructor in the Allied Subjects Group, Aviation Department, The Transportation School, Fort Eustis, Va. He was formerly stationed at Fort Belvoir, Va.

Robert M. Benson (M) has organized Inertial Instruments, Inc., 2029 Broadway, Santa Monica, Calif. As President, he will direct the company's activities in the mass flowmeter field. He was formerly Vice-President and Western Manager of Gyromechanisms, Inc.

Frederick Berger (TM) has joined Grumman Aircraft Engineering Corporation as a Propulsion Engineer. He was formerly a Stress Engineer with Goodyear Aircraft Corporation.

Thomas F. Bergmann (M) has joined the commercial sales staff of Lockheed Aircraft Corporation's California Division. He was formerly Sales Manager of the Wright Aeronautical Division of Curtiss-Wright Corporation.

James E. Boyce (M) has been promoted to Commercial Sales Manager of the California Division of Lockheed Aircraft Corporation.

Bernard Budiansky (M) has joined the faculty of Harvard University as Associate Professor of Structural Mechanics in the Division of Engineering and Applied Physics. Formerly with NACA, he was Head of the Structural Mechanics Branch of the Structures Research Division at Langley Aeronautical Laboratory.

Alfred J. Carah (AF) has been named Assistant for Component Design in the new Missiles Engineering Department of Douglas Aircraft Company, Inc. He was formerly Assistant Chief Design Engineer at Santa Monica.

T. F. Cartaino (M) is now with the Aircraft Division of the RAND Corporation, Santa Monica, Calif. He was formerly an Engineer in the Advanced Design and Development Section, Allison Division, General Motors Corporation.

Elmer S. Congdon (M), formerly a Helicopter Flight Test Engineer with McDonnell Aircraft Corporation, has joined Sikorsky Aircraft Division of United Aircraft Corporation, Bridgeport, Conn., as an Assistant Project Engineer.

Vernon G. Crudge (M), New York aviation consultant, has been retained by Boeing Airplane Company.

Ray D. Gardner, Jr. (M), has been promoted to Project Engineer of the Long-Range Interceptor Program at Northrop Aircraft, Inc., Hawthorne, Calif.

D. R. Gero (AF) has been promoted to Vice-President and Airborne Operations Manager of G. M. Giannini & Co., Inc., Pasadena, Calif.

Bernard Goldman (AM) has been promoted to Liaison Engineer and Maxwell Bernson Publications Department Editor at Ford Instrument Company, Division of Sperry Rand Corporation, Long Island City, N.Y. A former Naval aviator and technical writer, he will represent the company on Bureau of Aeronautics contracts.

Edward M. Greer (M), President of Greer Hydraulics, Inc., has been elected Chairman of the Board of Directors of Greer Marine Corporation, a wholly owned subsidiary.

Maxwell W. Hunter (AF), formerly Assistant Chief Project Engineer for Missiles, Douglas Aircraft Company, Inc., has been appointed Design Engineer of the new Missiles Engineering Department.

Robert L. Johnson (M), former Chief of the Automatic Control Systems Section, has been named Assistant Chief Missiles Engineer of Douglas Aircraft Company, Inc.

John S. Attinello, MIAS, has joined Fairchild Aircraft Division as Assistant Chief of Research in Preliminary Design. Formerly, he was with the Navy Bureau of Aeronautics and was also Secretary of the IAS Washington Section.

Brig. Gen. H. Franklin Gregory, USAF, AFIAS, Air Attaché of the American Embassy in Paris, France, has been reassigned as Commander of the USAF Office of Scientific Research in Baltimore. He takes command February 20.

Eugene C. Kaliher (M) has been appointed Engineering Personnel Manager of the new Missiles Engineering Department of Douglas Aircraft Company, Inc. He was formerly Assistant Project Engineer for Guided Missiles Projects.

James B. Kelley (M) has joined the New York State Department of Commerce, Albany, N.Y., as Consultant on Technical Industrial Research. He was formerly Technical Director of the Physics Research Laboratory, Inc., West Hempstead, N.Y.

T. Arthur Kvaas (M) has been promoted to Chief of Preliminary Design, Missiles Engineering Department, Douglas Aircraft Company, Inc. He was formerly an Assistant on the Missile Design Staff.

Samuel Levy (M) has joined General Electric Company as Manager of Stress Analysis Engineering in the Special Defense Projects Department, Schenectady, N.Y. He was formerly a physicist in Division 6.4, National Bureau of Standards, Washington, D.C.

Robert A. Manske (TM) has joined Bendix Aviation Corporation as an Engineer in the Analysis Group, Missile Section, Bendix Products Division, Mishawaka, Ind. He was formerly an Engineer in the Analytical Section of the Air Arm Division, Westinghouse Electric Corporation, Baltimore.

Philip W. McLane (M) has been promoted to Chief Engineer of Fletcher Aviation Corporation, Rosemead, Calif.

Franklin K. Moore (TM), formerly of Lewis Flight Propulsion Laboratory, NACA, has been appointed Head of the Aerodynamic Research Department at Cornell Aeronautical Laboratory, Inc.

Gordon Rosenthal (M) has joined Beech Aircraft Corporation as Group Engineer—Aerodynamics. He was formerly Group Leader—Aerodynamics at Canadair, Ltd.

Lloyd E. Schumacher (M), former Sales Manager, has been elected Vice-President in charge of Sales and Customer Relations

(*Continued on page 52*)

Hugh L. Dryden, Director of the National Advisory Committee for Aeronautics, served as President of the IAS in 1943. Before joining the NACA in 1947, the noted physicist had been with the National Bureau of Standards 29 years. At the age of 21, he became Chief of its Aerodynamics Section and later was successively Chief of the Mechanics and Sound Division, Assistant Director, and Associate Director.

Born in Pocomoke City, Md., in 1898, Dr. Dryden was graduated from Johns Hopkins University in 1916 and obtained his Ph.D. in physics and mathematics in 1919. He has six honorary degrees. An Honorary Fellow of the IAS and a Fellow of the Royal Aeronautical Society, he delivered the second Wright Brothers Lecture in 1938 and the Wilbur Wright Memorial Lecture of the RAeS in 1949. Recently, Dr. Dryden was named the Wright Brothers Medalist for 1955, having previously been awarded the Daniel Guggenheim Medal in 1950 and the Sylvanus Albert Reed Award in 1940. He was President of the Washington Academy of Sciences in 1946. He has served the U.S. Government on numerous scientific advisory committees, including AGARD, the Scientific Advisory Board of the Air Force, and the Research and Development Board of the Department of Defense. For his aid in developing guided missiles, Dr. Dryden was awarded the Medal for Freedom and the Presidential Certificate of Merit.

A Salute to Hugh L. Dryden . . .

There are many reasons why members of this organization are indebted to the NACA's director. As a Charter Member, a Past President, a long-time Council Member, and an active participant in many IAS affairs, Dr. Dryden has made long and notable contributions to the work of the Institute.

In one area in particular he has left an indelible mark. For the past 15 years, he has been Editor of the JOURNAL OF THE AERONAUTICAL SCIENCES. His sound judgment and wise guidance in the selection and preparation of its papers for publication have put the JOURNAL in the forefront of the world's scientific publications. He has been assisted by editorial committees in the several technical fields and by a competent staff, but he has been largely responsible for the technical material that has appeared between the familiar blue covers since 1942.

A simple scanning of all the papers that have come to hand in the past 12 years or so would have provided an almost full-time job for an ordinary man. But Dr. Dryden is not an ordinary man. In his deceptively easy-going and quiet way, he runs a wide variety of operations in the national defense network. Outside of NACA, he is an active member of an astounding number of boards and committees. He is U.S. representative to AGARD and seldom misses any important gathering of aeronautical scientists and physicists around the world. And yet, with all his commitments, he has always found time to look over JOURNAL papers, confer with our editors, and correspond with authors on technical questions.

But Hugh Dryden, as a human being, has physical limits. He can handle only so much at a time. A year or more ago, he let us know that he must, of necessity, reduce his total load and asked us to seek a replacement for him on the JOURNAL. We accepted his suggestion with reluctance, but circumstances left us no choice.

Working closely with Dr. Dryden, we have selected a new Editor for the JOURNAL. He has been on our editorial committees for a long time. He has been closely associated with Dr. Dryden on the JOURNAL and in many other capacities. He knows most of our staff people, and he knows how we work. We all feel that the selection of Dr. William Sears of Cornell will pose no transitional problems as he takes over the editorship on January first.

It is with great reluctance that we accept Hugh Dryden's resignation, but we speak for the entire member-

Editorial

ship in extending to him our thanks for the magnificent job he has done with the JOURNAL. He has set and has maintained a standard of excellence that will be difficult to surpass in the future.

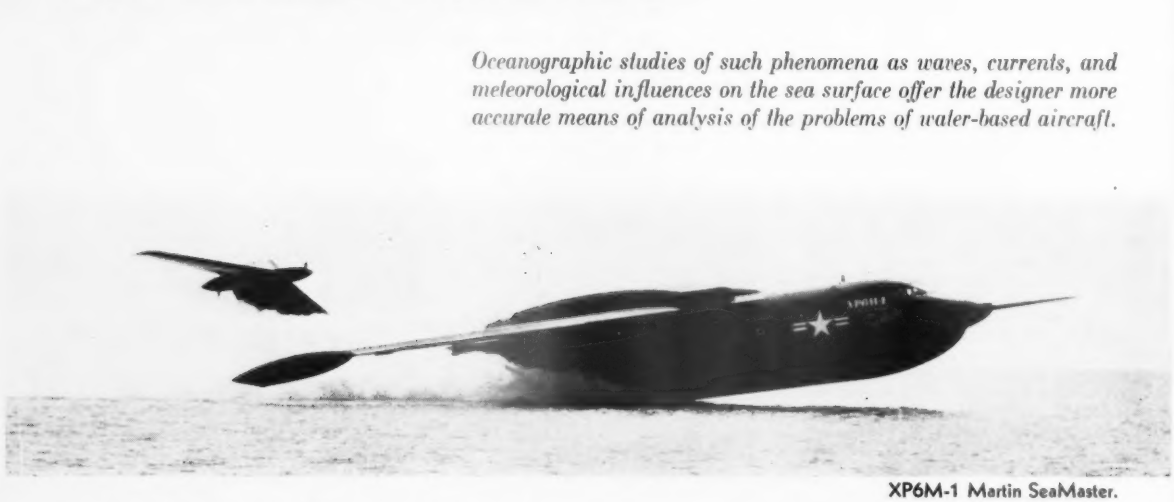
At the same time, we pledge to Dr. Sears the maximum of staff assistance and cooperation as he takes on his new assignment. We anticipate a continuation of JOURNAL activity on the level at which Dr. Dryden has placed it. We look forward to many years of this new relationship. S. P. J.

. . . and to the New *Journal* Editor

William R. Sears, FIAS, has been Director of the Graduate School of Aeronautical Engineering at Cornell University since 1946. Born in Minneapolis in 1913, he was graduated from the University of Minnesota in 1934 with a degree in aeronautical engineering and earned his Ph.D. at California Institute of Technology in 1938. From 1934 to 1939, he was a wind-tunnel assistant, instructor, and assistant professor at Caltech. He then joined Northrop Aircraft, Inc., as a consulting engineer and was chief aerodynamicist when he left the company for Cornell. Dr. Sears is a member of the IAS Meetings Committee and the Editorial Committee (Aerodynamics) of the *Journal of the Aeronautical Sciences*. He has served as a member of the USAF Scientific Advisory Board, the Naval Research Advisory Board, and the NACA Subcommittee on Fluid Mechanics.

Hope for Rational Seaplane Design

Oceanographic studies of such phenomena as waves, currents, and meteorological influences on the sea surface offer the designer more accurate means of analysis of the problems of water-based aircraft.



XP6M-1 Martin SeaMaster.

John D. Pierson* and Charles E. Carver, Jr.†
The Glenn L. Martin Company

FOR CENTURIES man has sailed upon the ocean, marveled at its serenity (a characteristic from which the great Pacific derives its name), struggled with its furious onslaught, and given up his life to it. That he once imagined himself as inhabiting its vast depths is strikingly epitomized by Jules Verne's great classic, *20,000 Leagues Under the Sea*.

To the casual observer, the sea appears unchanging. Oceanographers, however, have discovered that the ocean system is far from a static one and is characterized by changes which have proceeded relentlessly since the beginning of time.

These scientists the world over have been painstakingly studying such dynamic effects as the movements of currents, the existence of circulation patterns, and the extensive interplay between meteorological conditions and the sea surface with respect to the generation, propagation, and forecasting of ocean waves.

Further knowledge of the ocean has been gained from investigations of its marine life, explorations of the ocean floor, measurements of temperature and salinity distribution—to indicate but a few such systematic studies. However, it is the nature of surface waves and their interrelationship with meteorological conditions that concern the seaplane designer seeking to realize the full potential of water-based aircraft.

In the existing approaches to design from the standpoint of hydrodynamic analyses, the airplane is subjected to an idealized wave system consisting of regular sine or trochoidal components. Hull impact loads are determined from pressure equations containing empirical coefficients relating the load to the hull geometry and to the operational requirements of the airplane, reflective of some sort of sea state which has been shown to hold for similar designs. Resistance loads are generally obtained from model tests in a towing tank, either in the absence of waves or in the presence of simple, regular ones. The simplification in analyses afforded by such an idealized wave system, however, is achieved only at the expense of reality.

A glance at a typical ocean wave record will indicate that approximation of the sea surface by a regular sine or trochoidal wave train is far from being realistic. In fact, applying the methods of Fourier analysis to such a record indicates a lack of periodicity in the wave motion and presents a picture of complete randomness. One observes a surface configuration composed of waves of widely varying amplitudes—sometimes reinforcing each other, sometimes canceling each other, some superimposed on larger waves, all traveling at different velocities and often in different directions.

Measurements of the sea surface are now obtained through the use of three kinds of devices. One device which has been used extensively for obtaining wave records is the pressure-type recorder. The instrument is positioned near the ocean floor sometimes by a diver. A sensing element responds to the variation in pressure due to the passage of a wave, and a signal is generated which is transmitted to a pickup station, where the pressure record is converted to a corresponding wave amplitude record.

There are some limitations to the use and accuracy of these devices. They tend to filter out the short-period components of the wave spectrum because of lack of sensitivity. They yield erroneous readings in

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† Hydrodynamics Section.

instances where vertical accelerations of particles within the wave are appreciable, as is the case in shallow water for waves above a certain wave length, or for long-period waves entering shoaling water from the open sea. Instruments of this type located in relatively shallow water therefore are not well suited for determining the spectrum of wind-generated waves in the open sea, since the spectral composition in shallow water will deviate considerably from that at the point of origin.

Wave recording also is accomplished by means of a wave rod. Briefly, the device consists of a slender, buoyant staff marked with a scale and weighted with a damping device to restrict its vertical movement when waves pass. The height of the waves may be determined either by visual observation of the crest against the scale or by means of an attached resistance-type gage whose impulses are transmitted to a recorder. The greatest accuracy from wave rods is achieved with short-period waves; with long-period waves, however, the damping device is less effective, and the rod tends to rise upward with the wave, yielding false amplitude values.

Various forms of accelerometers have been in use aboard ships for measuring wave heights. The principle of operation depends upon a knowledge of the elevation of the water surface with respect to the vessel and the position of the vessel with respect to a fixed datum in space, the latter requiring the use of a gyroscope. With these data known, the acceleration of the water surface with respect to a fixed datum may be found and the wave profile determined after two integrations. The method is constantly being improved and promises to be a useful tool in obtaining wave records over a wide geographical range and under a broad range of conditions.

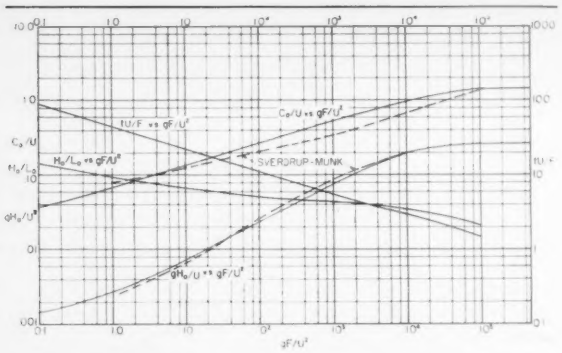
Wave data obtained from such devices are of little value unless correlated with attendant meteorological conditions such as wind velocity, duration and direction, air and water temperature, and barometric pressure. Weather maps over large portions of the oceans are of necessity woefully incomplete. A series of strategically placed buoys, capable of receiving and transmitting data on both the wave configuration and existing meteorological conditions, would represent an invaluable asset to the techniques of wave forecasting and contribute to a better understanding of the relationship between wind and waves.

Water-based aircraft such as the Martin XP6M SeaMaster, suitably equipped with recording instruments, could play an important role in this regard. Large areas could be covered in a relatively short time, landing periodically to observe the surface. An instrument for measuring and recording the surface configuration while in flight would make it possible to obtain the data even more quickly. Martin engineers are now investigating the possibility of developing such an instrument.

It appears feasible that an air-borne instrument may be constructed in the future, operating on the principle of radar echo return. Indeed, the so-called "sea return" which has plagued radar operators is in reality a crude indication of sea state. Roll[1] has described an instrument used aboard a vessel in the North Sea which utilized 3-cm. radar and an antenna rotating in 2.65 sec. Photographs, taken at 7.95-sec. intervals, clearly indicated the direction and distance apart of swell which in some cases was too low to be observed visually.

The extreme difficulty of adequately describing the complex motion of the sea is the greatest single deterrent to an analytical approach to seaplane design for

SeaMaster in flight.



Relationship between wind speed and duration, wave height and period, and fetch. These curves (reproduced from reference 3) summarize results of both laboratory and field tests obtained by these investigators and others. Also shown are curves for wave steepness and minimum duration as proposed by Bretschneider. For a given fetch and wind velocity, the tU/F curve gives the duration of wind after which no subsequent increase in wave height or period occurs. As the fetch increases, the duration time of the wind increases, and the limiting value of both the wave height and period increases. Of interest is the behavior of the C_0/U curve, sometimes defined as the "wave age," and the wave steepness curve, H_0/L. As the wave age increases, the steepness decreases, which agrees with observations that so-called "young sea" is steep whereas the slope of "old swell" tends to decrease.

open sea operation. The conventional methods of design involving regular wave trains are inadequate and incompatible with the actual random character of ocean waves.

What are the possibilities of ever developing a rational design procedure in the face of complexities which at first seem insurmountable? Fortunately we have powerful research tools in the form of generalized harmonic analysis and advances in mathematical statistics. These have been applied in relatively recent years to bring some order out of chaos in the pattern of sea waves.

For example, a comprehensive study of the relation between wind and waves was undertaken by Sverdrup and Munk[2] who compiled all available data on winds and waves and constructed plots depicting the wave characteristics as a function of wind duration, wind speed, and fetch. These data were coordinated by means of the following parameters:

$$\left.\begin{aligned} C_0/U \text{ vs. } (gF)/U^2 \\ gH_0/U^2 \text{ vs. } (gF)/U^2 \\ tU/F \text{ vs. } (gF)/U^2 \\ H_0/L_0 \text{ vs. } (gF)/U^2 \end{aligned}\right\} \quad (1)$$

where

H_0 = significant wave height, ft.
C_0 = wave velocity, ft./sec.
g = acceleration of gravity, ft./sec.^{2}
F = fetch, ft.
U = wind speed, ft./sec.
t = wind duration, sec.
L_0 = wave length, ft.

The term "significant wave height" as used by these authors refers to the mean amplitude of the highest one-third of all the waves considered, and the ratio H_0/L_0 is defined as the "wave steepness" or slope. A similar study on a laboratory scale was undertaken by Johnson and Rice.[3]

Within the last few years, powerful forces have been on the move to represent ocean wave configurations by statistical methods. Many observed but unexplained properties of wave behavior have been clarified on the basis of such theoretical considerations. Much of the impetus of these methods stems from the original work of Wiener[5] on generalized harmonic analysis as applied to the fields of communication and information theory. The work of Rice,[6] Tukey and Hamming,[7] and many others in these fields has been employed in the problem of ocean wave characterization with extremely promising results.

A mathematical model of a seaway has been proposed by Lonquet-Higgins[8] from which he was able to derive theoretical values of wave characteristics showing remarkable agreement with observation. The statistical representation of the wave system was of the form

$$\xi = [e^{j\sigma_0 t}] \int_{-\infty}^{\infty} A(\sigma) e^{i(\sigma - \sigma_0)t} d\sigma \quad (2)$$

where

ξ = wave amplitude
σ = angular frequency
t = time

The term in brackets represents a carrier wave of length $2\pi/\sigma_0$ whereas the integral in Eq. (2), $B(t) = \int_{-\infty}^{\infty} A(\sigma) e^{i(\sigma - \sigma_0)t} d\sigma$, is a slowly varying function which represents the envelope of the waves.

It may therefore be said that the probability distribution of the envelope function B is the same as that of the wave amplitudes in the carrier wave. The function B is assumed to be composed of wave contributions from various generating areas, and the phases of these contributions are independent of each other—i.e., B is composed of a large number of small vectors of random phase. The quantity $A(\sigma)$ is known as the frequency spectrum function of the given wave system and may be complex. It was further assumed that the spectrum $A(\sigma)$ was a single narrow frequency band of wave length $2\pi/\sigma_0$ and therefore of appreciable magnitude only for values of σ near σ_0.

In his analysis, Lonquet-Higgins was able to derive theoretical ratios of the mean height of all waves, H_{av}, and the significant height, $H_{1/3}$, and the mean of the one-tenth highest waves, $H_{1/10}$, and the significant height, $H_{1/3}$, as follows:

$$\begin{aligned} H_{av}/H_{1/3} &= 0.625 \\ H_{1/10}/H_{1/3} &= 1.27 \end{aligned} \quad (3)$$

These same quantities were computed by Munk[9] from actual ocean wave records and were found to have the values

$$H_{av}/H_{1/3} = 0.65$$
$$H_{1/10}/H_{1/3} = 1.27 \quad (4)$$

indicating remarkable agreement.

On the basis of observation of both the actual composite nature of sea waves, as well as theoretical considerations, Neumann[10] developed on expression for the spectral distribution of wave energy in terms of wave frequencies, having the form

$$dU_\nu = (-C\rho g^3 \pi^3 \nu^{-6}) \exp -2g^2/v^2\nu^2 \, d\nu \quad (5)$$

where

ν = wave frequency = $2\pi/T$ with T = period
ρ = mass density of the fluid
g = acceleration of gravity
v = wind velocity

The frequency of the optimum (greatest energy) band, ν_{max}, is easily determined from Eq. 5 by differentiating the energy distribution function with respect to ν, giving

$$\nu_{max} \cdot v = \sqrt{2/3}\, g \quad (6)$$

from which (v in knots) one finds

$$f_{max} = 2.475/v \text{ or } T_{max} = 0.405v \quad (7)$$

It is shown also that the total energy possessed by the composite wave pattern for the case of a fully risen sea increases with the fifth power of the speed of the wind.

Neumann also considers the case of a sea state that is not fully developed. In this instance, the characteristics of the wave spectrum depend upon both the duration of the wind and the fetch. Curves are presented for two situations—a constant wind blowing over an unlimited fetch so that the resulting sea state is dependent upon the wind duration and a wind of adequate duration blowing over a limited fetch. Thus, for a given wind speed and duration or wind speed and fetch, the energy in the resulting composite wave pattern may be found from which the average wave height, significant wave height, or 1/10 highest wave height may be computed. The range of significant wave periods in the spectrum may also be determined.

The problem of the response of a ship to the wave motion in a confused sea is considered by St. Denis and Pierson[11] in an extensive theoretical treatise. Of interest here is the mathematical model proposed by these authors for representing the seaway

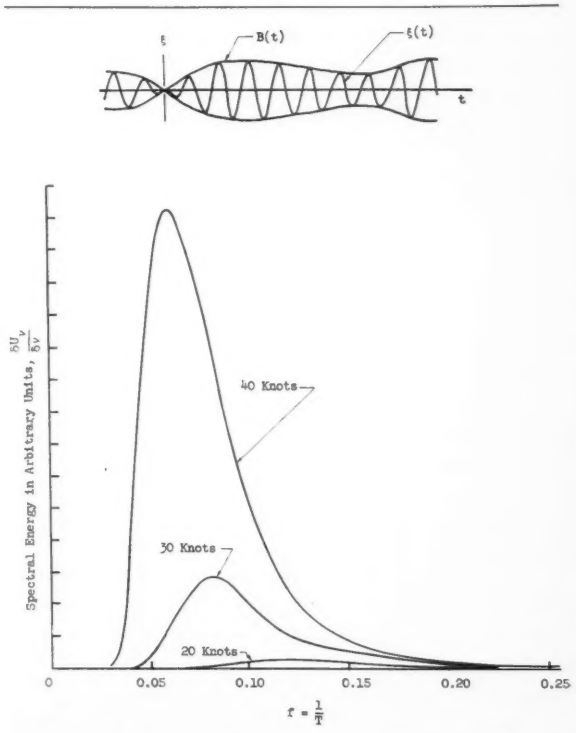
$$r(t) = \int_0^\infty \cos\,[\omega t + \epsilon(\omega)] \cdot \sqrt{[r(\omega)]^2 \, d\omega} \quad (8)$$

The term $r(t)$ represents the wave record as a function of time, and the integral on the right in essence consists of a basic sinusoidal wave modified by a random phase angle function, $\epsilon(\omega)$, multiplied by a function of the average squared wave amplitude associated with a given frequency. The term $[r(\omega)]^2$ is known as the energy spectrum from its relation to the average potential energy of the waves.

It was assumed in the statement of Eq. (8) that the random process so described at a given point was stationary—that is, the statistical properties of the waves remained invariant at a point. In addition, the waves represented by the mathematical model are short-crested, they are distributed in amplitude according to the Gaussian probability law, and their pattern is never repeated. Inasmuch as these characteristics are indigenous to actual ocean waves, the model proposed by these authors represents a significant advance toward the goal of characterizing the seaway.

Space limitations prevent further discussion of these findings or mention of the valuable results of many other investigations, such as the work by Marks[12] in determining a two-dimensional energy spectrum of the sea surface at the fringe of a storm area by means of high-altitude stereoscopic photographs and the study of ship motions in irregular waves by Fuchs and MacCamy.[13]

The extensive observations of actual ocean waves carried out by various oceanographic agencies throughout the world offer ample opportunity to check the appropriateness of mathematical formulations. To facilitate an exchange of information on such problems, Martin recently became a corporate associate of the Woods Hole Oceanographic Institution.



Top: Disturbance, $\xi(t)$ having a narrow frequency band and its envelope $[B(t)]$.

Bottom: Relative energy distribution $\delta U_\nu/\delta\nu$ in Eq. (5) for various wind velocities. Ordinate scale is expressed in arbitrary units because it is a function of the value of the constant C and the frequency interval δf. The curves show a significant increase in wave energy with increasing wind velocity and a characteristic shift in the maximun energy toward lower frequencies. Also at higher velocities the wave components contributing the most energy are confined to more narrow frequency band widths.

Despite notable achievements in providing a better concept of ocean wave motion, much remains to be learned about the sea. For example, temperature differences between the atmosphere and the water are believed to cause variations in the surface configuration owing to variations in the character of the boundary layer of the air-water interface (other conditions being equal). Most of the emphasis in seaway analysis has been placed upon those wave trains advancing from a generating area in the direction of the wind. On the other hand, little is known about the corresponding rarefactive or negative waves which travel in the opposite direction. More knowledge is needed regarding the effects of cross seas to explain the large, isolated intumescences or hummocks which have been observed in nature. In shallow water regions, one may expect that approaching deep water waves will undergo considerable deformation due to shoaling and will exhibit directional changes due to refraction. Information is required as to the spectral energy makeup of the wave train under these conditions where operation in shallow water is anticipated.

With reference to hull water loads for operation in the open sea, it appears that the most important parameter of the seaway in determining these loads is the distribution of wave slopes or steepness. It is necessary also to know the "length" of the slope with respect to the contact length of the aircraft, since it is clear that the same slope may be obtained for an infinity of combinations of wave height and length. Evidently the distribution of wave slopes and their "lengths" must be defined in a statistical sense for a given sea state in order to arrive at a rational approach to the determination of water loads. Much work remains to be accomplished in the area of statistical representations of wave slopes.

The advent of extended open sea operations as envisioned for the water-based airplane brings forth two important problems which must be solved in order to realize the full potential of the modern seaplane. The first concerns the useful life of the airplane in a fatigue sense. Specifically, what is the probable number of wave impacts expected during a given number of operational hours?

It will be readily apparent that an answer to this question requires a knowledge not only of the spectral makeup of a given sea but also of the variation of the wave spectrum with season for various anticipated zones of operation. Thus, an operational limitation is placed upon the airplane, a restriction which, if exceeded, is likely to cause structural failure through fatigue.

The second problem arises as a result of the increasing trend toward greater structural elasticity and is concerned with extreme wave conditions likely to cause immediate structural failure. Assuming that the forcing function represented by the waves could be adequately expressed statistically and that the vibrational modes of the elastic structure are known, it should then be possible to determine the response of the airplane to various sea states and thereby expose certain critical conditions.

Specifically, what is the probability that such critical conditions will be encountered during the operational life of the airplane? To seek an answer to this question in other than a statistical sense would be a hopeless task.

Despite the complex behavior of the oceans, much of the mystery surrounding the sea has been swept away particularly with respect to surface wave phenomena. Progress has been achieved in part by means of the mathematical tools of modern statistical theory corroborated by actual observations with specially developed wave measuring instruments. We believe that such realistic representations of the seaway ultimately will provide a more rational approach to the structural design of water-based aircraft from both the fatigue and maximum load standpoint.

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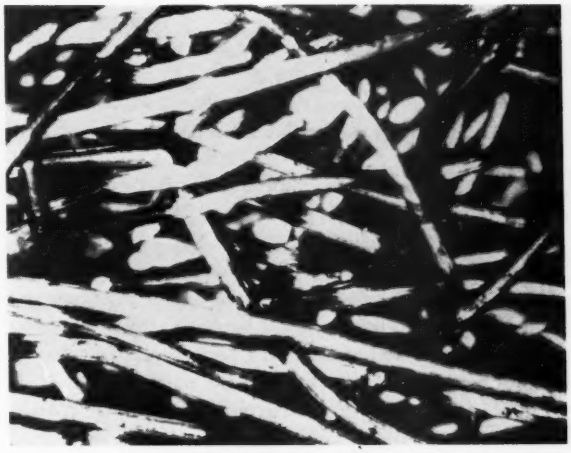
Development of a molybdenum brush that helps solve the problem of brush bounce and thus reduces electrical noise in high-altitude flight.

Fiber Metallurgy—Its Use for Slip Ring Brushes

H. B. Nudelman,* A. G. Metcalfe,† and C. H. Sump‡
Armour Research Foundation of
Illinois Institute of Technology



Structure of fiber metal brush.

Fiber Metallurgy

Fiber metallurgy can be defined as the study of materials based on the use of metal fiber to form bulk material. This new usage of metals was conceived in 1948 when short-length metal fibers were used to prepare filter materials.** Since these early efforts, the scope of fiber metallurgy has been extended to include such diverse applications as friction materials and slip ring brushes. A new slip ring brush material has been developed that has demonstrated excellent potentialities for use in high-altitude flight.

Before discussing brushes, perhaps we should say something about fiber metallurgy. The methods of powder metallurgy can be applied to the preparation of fiber metal material, but the new material has even greater possibilities when it is felted in a manner similar to the paper-making process. A slurry of metal fiber can be collected on a porous shape in much the same way that paper is manufactured. The felting method of preparation is a new contribution to metal technology.

The fiber metal structure has several distinct and unique advantages. Whether the initial forming operation is done by felting or by direct die-fill cold pressing, the fibrous structure takes advantage of the mechanism of interlocking. This advantage was shown when nickel felts, 98 per cent porous, could be handled readily in the "green" or unfired state. In fact, molybdenum fiber bodies with 65 per cent porosity demonstrated useful slip ring brush properties as cold pressed.

When a porous material is sintered, fibers add greatly to bonding efficiency. While a powder particle might be bonded to a few other particles, a single fiber can be bonded to many fibers. This fiber-to-fiber bond explains the superior strength and tenacity of highly fiber metal. It is in the aircraft industry that fiber metal has many potential applications, particularly for high strength-high porosity materials. Fiber metallurgy materials are being considered for use in deicing systems, boundary-layer control, and transpiration cooling. The fibrous structure shows less pressure drop across its section for either gas or liquid flow, in comparison with conventional powder metal. Beyond this it offers greater strength and toughness.

Slip Ring Brushes

At high slip ring surface speeds, difficulties with electrical noise are encountered with presently available brushes. Electrical noise has been thought to result from one of three sources. *First*, by the generation of thermal electromotive forces. At the point of contact between brush and slip ring, dissimilar metals could develop these emfs. The heat developed by friction during operation causes the generation of an emf, the point of contact acting in much the same manner as a thermocouple. Noise from this source, however, is solely an effect of material.

A *second* mechanism is contact resistance. In normal atmospheres, moisture and oxide films are present on the contact surfaces. Under favorable electrical and mechanical pressures, these films are broken down sufficiently to allow the passage of current. The process of film formation and breakdown is not uniform during slip ring operation and consequently results in varying contact resistance and signal voltage. Under constant conditions of speed and brush pressure, this effect is related to the contact materials also.

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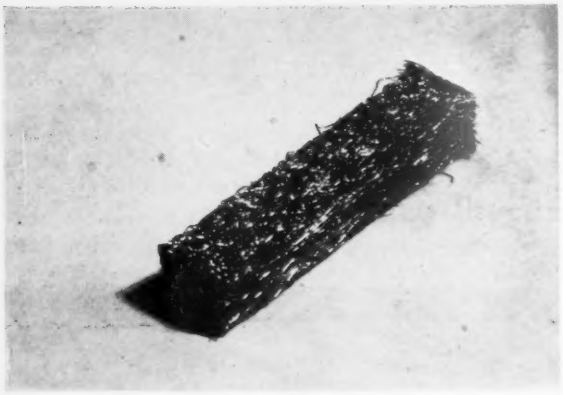

Fiber metal molybdenum brush.

A *third* source of noise is of a somewhat different nature. It involves brush bounce and loss of contact between brush and slip ring. The loss of contact appears to be related to the physical nature of the brush rather than the brush material. This phenomenon occurs with conventional solid brushes at high slip ring speeds. Brush bounce has an effect similar to varying contact resistance but is far more detrimental. The bounce breaks contact and current ceases to flow, with the result that open circuit voltage is impressed across the gap. Brush bounce appears to be related to the inability of solid materials to conform to the slip ring surfaces. At higher slip ring speeds, only a slight degree of surface irregularity is necessary to cause brush bounce and loss of contact. Even if the slip ring contact surface could be made perfectly smooth, uneven wear would roughen the surface and cause brush bounce within a short time. At high surface speeds, brush bounce cannot be avoided when using conventional solid brush material.

The solution to brush bounce—the major contribution to electrical noise—appeared to require the development of a conducting material capable of conforming to the slip ring surface at high speeds. The material should conform readily to the ring and maintain continuous contact with the slip ring surface. A porous body composed of metal fibers seemed to fulfill these requirements. Selection of high porosity developed a low bulk modulus, resulting in a flexible, easily deformed surface. The relatively high stiffness of the individual fibers gave rise to the "spring" characteristics necessary to maintain contact. Each individual fiber acted as a tiny brush. With hundreds of individual contacts, the loss of a small number of these through bounce or wear was not expected to affect overall body contact.

Fibrous molybdenum demonstrated greatly improved brush properties over graphite or silver-graphite. Although the fiber approach appeared to be sound, the selection of the proper brush and mating slip ring materials had to be made. It was suggested that metal combinations should be selected that show little or no tendency to alloy together, which would reduce the possibilities of welding at the points of contact. Avoiding wear by local adhesion is extremely important at high altitudes where normal surface films are not developed. The requirement for little or no alloying was met by the silver-molybdenum alloy system, which showed no solid solubility.* The high melting point of molybdenum (4,760°F.) was considered advantageous to resist the melting and softening effects of frictional heat. Furthermore, molybdenum had a high elastic modulus (50 by 10^6 lbs. per sq.in.). This fiber stiffness was expected to enhance the maintenance of contact. The user of silver for the slip ring was thoroughly consistent with its wide use in the field of electrical contact materials. Both materials fortunately had adequate electrical conductivity. The generation of thermal emfs appeared to present little difficulty. Up to the region of 1,200°F., the emf values of silver and molybdenum differ but slightly.

The nature of the metallic oxides of silver and molybdenum indicate that surface film formation at low altitudes would not present a problem. The oxides of silver become thermally unstable above 570°F. At lower temperatures, only slight pressures are necessary to clean the surface of the soft oxide film. Furthermore, the trioxide of molybdenum volatilizes readily when heated.

Brushes of molybdenum fiber† were prepared using the recently developed techniques of fiber metallurgy. Electrodeposited fine silver was used for slip ring contact surfaces. The first tests of the combination demonstrated extremely low noise levels.‡ This led to an investigation of details of metal fiber brush preparation with respect to electrical noise and wear. Brush density, fiber diameter, and fiber length were the variables considered. The optimum physical properties determined for this application were

Brush density	35 per cent
Fiber diameter	0.0035 in.
Fiber length	1.5 in.

Increasing the brush size was found to improve performance still further by providing many more individual fiber contacts. Test brushes were given conventional as well as simulated high-altitude tests (test brush size: 0.25 by 0.50 by 1.0 in.). The 0.50 by 0.25 in. face was the test surface across which a brush pressure of 5 lbs. per sq.in. was applied. An RMS noise voltage of 0.18 millivolts was recorded under test conditions of 20,000 ring surface ft. per min. and a brush current of 100 milliamp. d.c. running against an electrodeposited silver slip ring. Brush wear was 0.70 per cent per hour; slip ring wear was less than 1 per cent per hour. Surface speeds up to 30,000 ft. per min.

(*Continued on page 44*)

* Hansen, M., *Der Aufbau der Zweistofflegierungen*, 1943.

† Supplied by Fansteel Metallurgical Corporation, North Chicago, Ill.

‡ ARF Electrical Engineering Department.

A description of a column test program conducted to determine design column curves for stainless steel, including a discussion of the use of the tangent and reduced modulus.

Column Curves for Type 301 Stainless Steel*

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FIG. 1.

INTRODUCTION

STAINLESS STEEL is a chromium-nickel steel alloy of high strength. Tough and ductile, it is an important structural material and is used in the railcar, truck trailer, and aircraft industries. Unlike most steel alloys, its high strength is derived from cold rolling rather than from heat treatment. Because of this, stainless steel is anisotropic in all but the annealed state. Since this material has different properties in different directions and no definite yield point, except by definition, it has been difficult to predict accurately the load capacity of stainless steel columns.

For a material stressed below the proportional limit, the maximum apparent stress that a column with a stable cross section can sustain is given by the Euler equation

$$P/A = \pi^2 E/(L/\rho\sqrt{c})^2$$

where

E = Young's modulus of elasticity
L = length of column
ρ = radius of gyration
c = constant denoting degree of end fixity.

For a material with no definite elastic limit, such as stainless steel, the above expression is not valid. Historically, F. Engesser proposed that the tangent modulus be used in place of Young's modulus for columns stressed beyond the proportional limit. Subsequently, Considere, Engesser, and later von Kármán suggested that a reduced modulus be used. When a column approaches its critical load and begins to deflect laterally, the strain in the convex side decreases, and the material in unloading behaves according to Young's or the initial tangent modulus. On the other hand, the strain in the concave side increases, and the material behaves according to the instantaneous tangent modulus. These two moduli are combined into a single reduced modulus for a column with a solid rectangular cross section.

$$\bar{E} = 4E_\sigma E/(\sqrt{E}_\sigma + \sqrt{E})^2$$

where

$\bar{E}$ = reduced modulus
E_σ = tangent modulus

Critical column loads computed by the reduced modulus theory are somewhat higher than those computed by the tangent modulus theory. According to more recent literature[1] on inelastic columns, a straight column should fail at a load somewhere between the loads given by the reduced and tangent modulus theories. Furthermore, the more gradual the transition to the inelastic region of the stress-strain curve for the material, the higher is the critical load the column will sustain above that indicated by the tangent modulus.

In stainless steel design, it is claimed that the use of tangent modulus column curves for predicting allowable column loads usually gives loads lower than test values. Consequently, some designers[2] have advocated that the reduced modulus be used for stainless steel because it gives higher values, which agree better with test results.

As part of the research necessary in the preparation of a design specification for Type 301 stainless steel, it is necessary to decide which modulus to use in computing column curves. Since the literature and other available information yielded inconclusive data, a test program was conducted. More than 200 column specimens of annealed, 1/4-, 1/2-, and full-hard material, in slenderness ratios varying from 15 to 120, were tested.

The research disclosed that theoretical column curves based upon the reduced modulus agree better with the

* This paper is based upon research conducted by the Franklin Institute Laboratories for Research and Development under the sponsorship of the American Iron and Steel Institute for the preparation of a design specification for the use of Type 301 stainless steel.

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‡ Research Engineer, Engineering Mechanics Section.

Table 1. STAINLESS STEEL FOR COLUMN TESTS

Hardness	Width (in.)	Thick (in.)	Yield Point (psi) Tension (from Co.) Long.	Tension (from Co.) Transv.	Comp. (from F.I.) Long.	Comp. (from F.I.) Transv.	Drawing Number	Supplier	Heat	Coil No.
Annealed	12	.025	40,800	40,300	37,000		SK-10-2316	Allegheny Ludlum	22893	
	12	.050		36,450	29,000		SK-9-2316	U. S. Steel		
		.075			40,000		SK-12-2316	Budd Company		Budd Co. 766B61
1/4 Hard	12	.020			74,000	105,000	SK-5-2316	Allegheny Ludlum	71796	
	24 12	.045			47,000	78,000	SK-13-2316	U. S. Steel		9-26W-180
	12	.062	98,010		60,000	99,000	SK-7-2316	Republic Steel	E-21175	
	24	.076			99,000	103,000	SK-17-2316	Allegheny Ludlum		
1/2 Hard	12	.025			96,000	133,000	SK-1-2316	Allegheny Ludlum	42759	
	12	.050			87,000	131,000	SK-6-2316	Allegheny Ludlum		
		.076			89,000	130,000	SK-15-2316	Budd Company		Budd Co. 673B101
Full Hard	12	.030	147,200		90,000	167,000	SK-8-2316	Republic Steel	E-20658	
	24	.030				206,000	SK-8-2316	Allegheny Ludlum		
	24	.045				213,000	SK-16-2316	U. S. Steel		1-16A-94
	12	.050			147,000 155,000		SK-18-2316	Allegheny Ludlum		
	24 12	.076			104,000	185,000	SK-11-2316	U. S. Steel		11-7x-364 11-7x-364

test results for longitudinal grain specimens than do those based upon the tangent modulus. On the other hand, for transverse grain specimens, column curves based upon the tangent modulus agree better with the test results than do those based upon the reduced modulus. (A "longitudinal" specimen is one made with the grain parallel with the long axis of the column, and a "transverse" specimen is one made with the grain perpendicular to the long axis of the column.)

Test Specimens

The tests were conducted on 0.025, 0.050, and 0.072 thick, annealed material; on 0.020, 0.045, 0.062, 0.076 thick, 1/4-hard material; on 0.025, 0.050, and 0.075 thick, 1/2-hard material; and on 0.030, 0.045, 0.050, and 0.076 thick, full-hard material. For 1/4-, 1/2-, and full-hard material, specimens were made with the grain in both the longitudinal and transverse directions.

The specimens consisted of two hat sections shot welded together to form a closed column. This column was selected because it is a common type of structural member in stainless steel. The width of flats was chosen so there would be no local instability. The ends of the specimens were ground parallel to one another within 0.0003 in. The cross section of a typical column specimen is shown in Fig. 1.

In order to determine the modulus of elasticity for the material from which the column specimens were made, compression tests were run on flat strips $^1/_2$ in. wide by $2^1/_4$ in. long by the thickness.

The cross-sectional area of both column and strip specimens was obtained by weighing each specimen and dividing the weight by the length and density. As carefully as the column specimens were made, there was, nevertheless, some variation in the depth of section along the length. Therefore, in order to compute the representative moment of inertia, the average of several depth (or width) readings was taken.

The steel used in the various tests is listed in Table 1. This table shows hardness, thickness, yield points, and the company supplying the steel. The tension yield points, were supplied by a company and were given in but a few cases. Since we were concerned only with compression, we determined only the compressive yield points. Table 2 gives the chemical compositions of some of the steel used.

Test Equipment

The tests were performed on a Baldwin-Tate-Emery Universal Testing Machine with a maximum loading range of 120,000 lbs. This machine was officially calibrated in June, 1953, and again in January, 1955, to an accuracy of 1.0 per cent. Steel guides (Fig. 2) made from drawings[3] prepared by the Bureau of Standards were used to support the flat strips during compression tests. Two Tuckerman optical strain gages of 1-in. gage length and an Autocollimator were used. A clamp was made to hold the gages with uniform pressure. Two Huggenberger strain gages of 1-in. gage length were also used.

A small knife edge was used for loads up to 25,000 lbs. and a larger one for loads up to 80,000 lbs. The smaller knife edges and the plates upon which they bore were made of 1020 carbon steel hardened to Rockwell

Table 2. CHEMICAL ANALYSES OF STAINLESS STEEL

Hardness	Thick (in.)	C	Mn	P	S	Si	Cr	N_1	T_1	C_b	Mo	Cu	N_2	Supplier
Annealed	.025	.090	.62	.21	.009	.39	17.19	7.58						Allegheny Ludlum
		.085	.67	.22	.015	.39	17.19	7.61	.032	trace			.038	
Annealed	.050	.10	1.12	.031	.022	.31	17.91	6.97			.13	.20		U. S. Steel
Annealed	.075	.096	1.36				17.96	7.86						Budd Company
1/4 Hard	.062	.116	1.19	.30	.23	.49	17.88	7.48			.21	.16		Republic Steel
1/2 Hard	.075	.10	1.30				17.21	6.94						Budd Company
Full Hard	.030	.113	1.26	.036	.032	.47	17.85	7.22			.16	.17		Republic Steel

C63. The larger knife edges and bearing plates were of 1020 carbon steel (Rockwell C60) and had carboloy inserts (Rockwell 94A) on the bearing edges and surfaces.

For the columns tested between knife edges, the true length of the column was computed by the method suggested by Osgood.[4] The knife edges were calibrated against solid steel and aluminum rods and showed that pin-end conditions existed within ± 1 per cent.

Test Procedure

Each specimen was placed in the machine between the knife edges. The knife edges were then aligned by means of square edges placed along their sides and ends. To ensure that each specimen was centered as perfectly as possible, Huggenberger tensometers were placed on the flat sides of the column (the extreme fiber in bending). When the specimen was properly centered, the gages showed equal strain increments during loading. For the test arrangement see Fig. 3.

For the cases where the knife edges could not be used (for some of the 1/2-hard and full-hard specimens), the specimens were placed between parallel plates in the testing machine, and the ends were considered fixed.

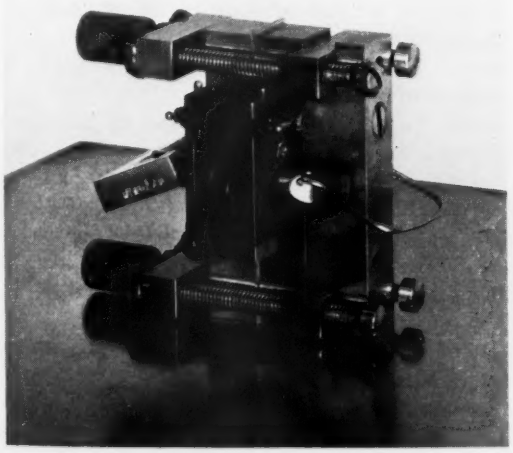

Fig. 2. Steel guides.

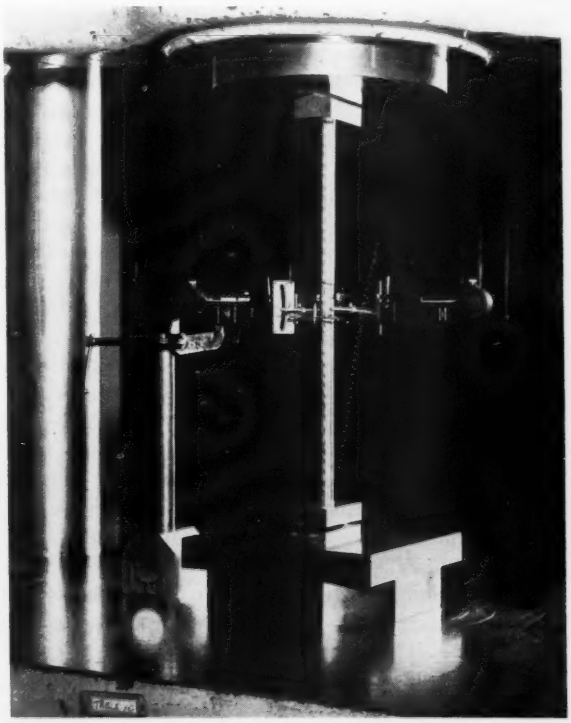

Fig. 3. Test arrangement.

Rate of Loading

The loading technique used in the tests varied according to whether the column was long or short. The long columns would fail before the material was stressed near the yield point, and therefore transient creep was not a significant factor. Hence the longer columns were loaded at a faster rate. For the intermediate and short columns, however, the rate of loading was determined by how fast indicators on the strain gages were moving. It was necessary to hold these higher loads until both indicators were moving slowly enough to be reasonably certain that the column would continue to carry the load indefinitely. Sometimes, this would be as long as half an hour. To be conservative, it would have been best to hold the load until the motion of the indicators was imperceptible and to make the loading increments small. In order not to spend too much time on one specimen, however, it was necessary to choose reasonable increments and to change the loading before the motion of the strain gage indicators became imperceptible. In establishing our technique, we loaded one specimen in the manner described above, while a duplicate specimen was loaded extremely rapidly (2,000 or 3,000 lbs. per min.). The specimen that was loaded rapidly failed at a load over 20 per cent higher than that of the specimen loaded slowly.

Test Results

There were 21 separate sets of column tests. There were three sets of tests on annealed material and six sets each on 1/4-hard, 1/2-hard, and full-hard material including longitudinal and transverse grain directions. The data for each of these tests—including the calibration of the knife edges, the section properties of the column, the stress-strain curves of the material, the computations of the column curves based upon the reduced and tangent moduli, the reduction of the actual test data, and the individual graphs showing the comparison of the test data with the column curves based upon the reduced and tangent moduli—are found in the Appendix to *The Franklin Institute Report A-2316-3*.

Before starting this test program we suspected that the additional hardening to which stainless steel is subjected in the course of forming a section might account for the fact that a column can sustain a load higher than that predicted by using the tangent modulus elasticity. Accordingly, a small program was conducted to determine the magnitude of this effect. These test results indicated that the operation of forming a stainless steel column increases its load capacity; that the increase is greatest in annealed material, decreasing as the material becomes harder; and that the effect is less great in columns where the transverse grain of the material coincides with the long axis of the column. In the course of this program, we also studied the effect that spot welding has on stainless steel and learned that spot welding reduces the average modulus of elasticity. The effect is least apparent in annealed material, becoming more pronounced as the hardness increases. These two effects—forming and welding—are considered in the interpretation of the column test results.

Comparison of Test Results with Column Curves Based on the Reduced and Tangent Moduli

In Figs. 5 through 11, the test points are compared with theoretical column curves based on the tangent reduced moduli. Since the stress-strain curves varied for each thickness in each hardness (see Fig. 4), it was necessary to draw separate column curves for each thickness. Thus there are as many column curves in each figure as there are specimens of different thicknesses. Also, the test points are plotted twice in each figure, once to show comparison with the column curves based on the reduced modulus and the second time to show comparison with the column curves based on the tangent modulus. Since forming the rounds of a stainless steel column has an effect on its load capacity through additional hardening of the material in the rounds, the percentage of cross-sectional material in the rounds for each group of specimens is also shown on the figures.

For the annealed material (Fig. 5), the test points are much higher than either the reduced or tangent moduli column curves in the short-column range but slightly lower in the long-column range. In the short-column region the stresses are higher, and the effect of forming the column—i.e., effect of the rounds—is more pronounced on the load capacity than in the long-column range where the stresses are lower. It is also noticed in the short-column range that the columns having a greater percentage of material in the rounds carry a higher load. Thus the column of 0.072 thick material with 37 per cent of round material sustains a higher stress than the 0.025 column with 21 per cent of round material, which in turn sustains a higher stress than the 0.050 column with 16 per cent of round material.

The agreement of the theoretical column curves based upon the reduced modulus with the test data is better than that of the curves based upon the tangent modulus. This is due to the greater load capacity of the column because of forming rather than to the column behaving according to the reduced modulus theory. This fact is more apparent in the higher hardnesses, as will be shown.

Since the tests were completed, we have learned from members of the American Iron and Steel Institute subcommittee that the stress-strain curve for the 0.050 annealed material is not typical of annealed stainless steel. The Research Laboratory of the Allegheny Ludlum Steel Corporation tested a sample of the same 0.050 material and confirmed our stress-strain curve. They suspect that the shape of the curve may be due to the Bauschinger effect induced by the stretcher-leveling operations.

Looking at the individual sets of 1/4-hard, longitudinal grain, column tests (Fig. 6), we see that the test data for columns made of 0.020 thick material agree almost

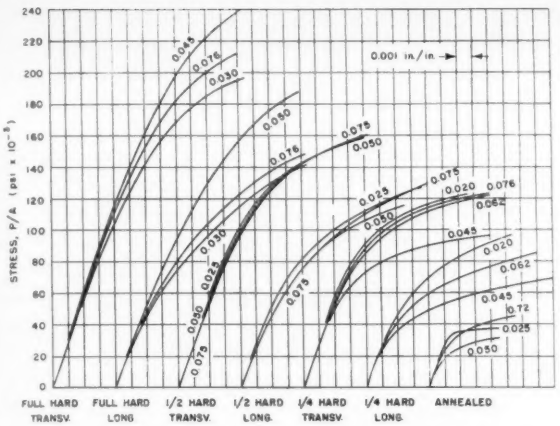

FIG. 4. Compressive stress-strain curves, Type 301 stainless steel.

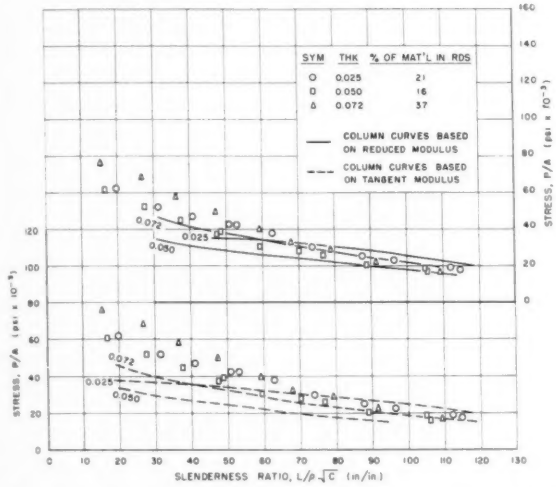
SYM THK % OF MAT'L IN RDS
0.025 21
0.050 16
0.072 37
COLUMN CURVES BASED ON REDUCED MODULUS
COLUMN CURVES BASED ON TANGENT MODULUS
STRESS, P/A (psi x 10⁻³)
SLENDERNESS RATIO, L/ρ√c (in/in.)

FIG. 5. Comparison of test data with tangent and reduced moduli column curves, annealed.

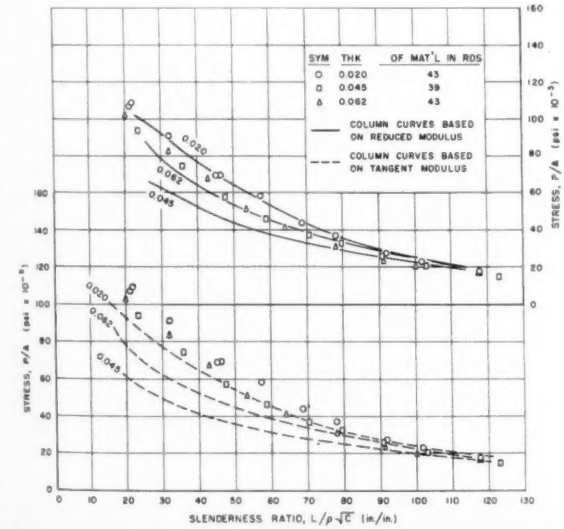
SYM THK % OF MAT'L IN RDS
0.020 43
0.045 39
0.062 43
COLUMN CURVES BASED ON REDUCED MODULUS
COLUMN CURVES BASED ON TANGENT MODULUS
STRESS, P/A (psi x 10⁻³)
SLENDERNESS RATIO, L/ρ√c (in/in.)

FIG. 6. Comparison of test data with tangent and reduced modulus column curves, 1/4-hard longitudinal.

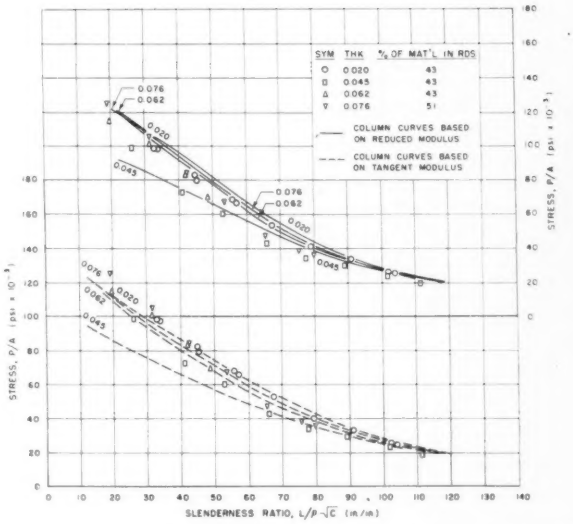
SYM THK % OF MAT'L IN RDS
0.020 43
0.045 43
0.062 43
0.076 51
COLUMN CURVES BASED ON REDUCED MODULUS
COLUMN CURVES BASED ON TANGENT MODULUS
STRESS, P/A (psi x 10⁻³)
SLENDERNESS RATIO, L/ρ√c (in/in.)

FIG. 7. Comparison of test data with tangent and reduced modulus column curves, 1/4-hard transverse.

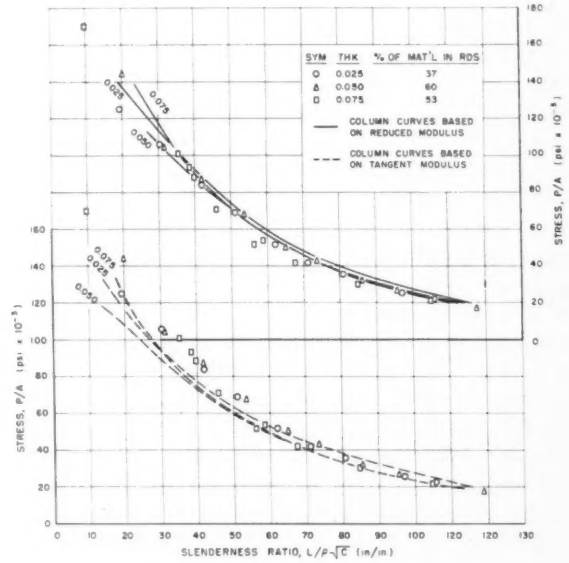
SYM THK % OF MAT'L IN RDS
0.025 37
0.050 60
0.075 53
COLUMN CURVES BASED ON REDUCED MODULUS
COLUMN CURVES BASED ON TANGENT MODULUS
STRESS, P/A (psi x 10⁻³)
SLENDERNESS RATIO, L/ρ√c (in/in.)

FIG. 8. Comparison of test data with tangent and reduced modulus column curves, 1/2-hard longitudinal.

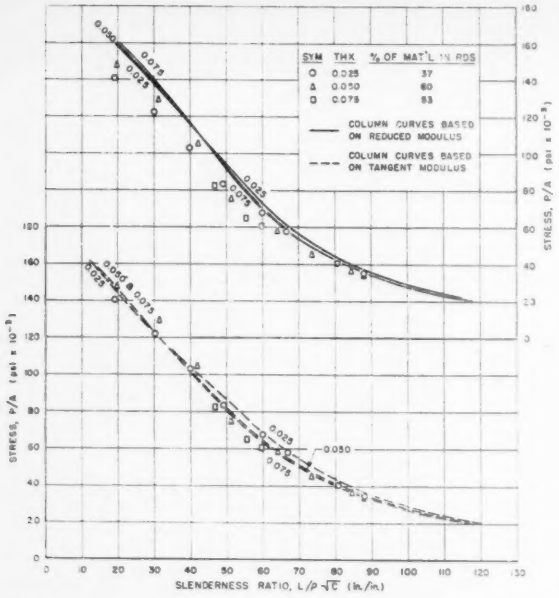
SYM THK % OF MAT'L IN RDS
0.025 37
0.050 60
0.075 63
COLUMN CURVES BASED ON REDUCED MODULUS
COLUMN CURVES BASED ON TANGENT MODULUS
STRESS, P/A (psi x 10⁻³)
SLENDERNESS RATIO, L/ρ √(E/σ) (in./in.)

FIG. 9. Comparison of test data with tangent and reduced modulus column curves, 1/2-hard transverse.

perfectly with the column curves based upon the reduced modulus, that the test data for the 0.062 columns agree somewhat less perfectly with the reduced modulus column curve, and that the data for the 0.045 columns are appreciably higher than the reduced modulus column curve in the low-slenderness ratio regions. These differences in agreement can be explained not by differences in the percentage of material in the rounds, which is essentially the same for each material, but by differences in the stress-strain curves for each material. Referring to Fig. 4 for $^1/_4$-hard longitudinal, it is seen that the curve for the 0.020 material is highest, that for the 0.062 is lower, and that for the 0.045 the lowest. Now, our past experience has shown that the greatest increase in load capacity due to forming is in material with the lowest yield strength. Thus we would expect the 0.045 columns to exhibit the greatest increase in load capacity over that indicated by theory for the unformed material, the 0.062 columns less increase, and the 0.020 columns the least. The curves and test data in Fig. 6 confirm this. Fig. 6 shows that, as in the case of the annealed specimens, the column curves based on the tangent modulus agree less with the test points than do those based on the reduced modulus, except when slenderness ratios exceed 100. This is understandable because the effect of forming is usually negligible in the low stresses which exist in the higher slenderness ratios.

In the $^1/_4$-hard, transverse grain, column tests (Fig. 7), it is seen that the test points for all columns except those with high slenderness ratios are generally below the column curves based upon the reduced modulus; whereas the test points agree fairly well with the column curves based on the tangent modulus except in slenderness ratios up to 40. The test data agree better with the tangent modulus column curves than with the reduced modulus column curves because the stress-strain curves for the transverse grain material (Fig. 4) are relatively high, and there is, therefore, little additional hardness and thus load capacity to be gained by forming the rounds.

In the $^1/_2$-hard, longitudinal grain material (Fig. 8), it is seen again, as in the case of the $^1/_4$-hard, longitudinal grain material, although not to the same pronounced extent, that the column curves based on the reduced modulus agree extremely well with the test data, except for several points, and much better than do the curves based on the tangent modulus. (There are four or five points in the 0.075 data that appear low in the middle portion of the curves. We rechecked our data and saw that the strain readings diverged sooner than did the readings for the specimens whose loads agree better with theory. We therefore suspect that these low points were due to slight eccentricities in column alignment.) Again, this can be explained by the added load-carrying capacity of the rounds due to the increased hardness caused by forming. As for the test points themselves, it is seen that the points are aligned as expected, based upon the percentage of round material in the cross section and upon the stress-strain curves (Fig. 4). Based solely on the stress-strain curves, the test points for the 0.025 thick specimens should be slightly higher than those for the other specimens. However, the percentage of material in the rounds in the 0.050 and 0.075 specimens is 25 to 30 per cent more than in the 0.025 specimens. And, since this material is further hardened during forming, we would expect the specimens with the greater percentage of round material to carry more load. This, we notice, is the case.

In the $^1/_2$-hard, transverse grain material (Fig. 9), curves based upon the tangent modulus agree almost perfectly with the test data and much better than do those based on the reduced modulus. Since there is little additional hardness to be gained by forming $^1/_2$-hard, transverse grain material, the fact that the specimens have different percentages of round material is of no significance.

Because of the limitations of our knife edges, it was decided to test the short columns with fixed ends by simply resting the parallel-ground ends against bearing plates in the testing machine. (This method is used successfully by the Aluminum Company of America in their Research Laboratories at New Kensington.) However, since some of the test data for the 0.075, $^1/_2$-hard specimens is low in the short-column region because of local crippling, this data has not been included in Figs. 8 and 9.

In the full-hard, longitudinal tests (Fig. 10), curves based upon the reduced modulus agree better with the data than do those based upon the tangent modulus. Ordinarily, this might not be expected because at this hardness there is not much more to be gained by the additional forming that occurs in the rounds. However, there is such a high percentage of material in the rounds (70 per cent in the 0.050 and 0.076 specimens)

that, while the unit gain in load capacity is small, the total gain is significant. It should be noted, though, that the percentage of material in the rounds of the 0.030 specimens is but 40 per cent, and yet their test points agree excellently with the reduced modulus column curve.

In Fig. 11 it is seen that the column curves based upon the tangent modulus agree almost exactly with the test data, demonstrating again that where there is little to be gained by additional hardening due to forming, column curves based upon the tangent modulus will agree much better—if not exactly—with test data than will column curves based upon the reduced modulus.

Because of the difficulty in obtaining wide sheets of full-hard, transverse grain specimens, not as many test data are available for this material as for others. Also, in some of the high-stress, short-column specimens, we suspect that local crippling caused ultimate failure rather than column action. This would account for the low test values of the shortest columns.

Conclusions

Test Specimen

Since it has been demonstrated that forming a member affects its strength, the number of rounds are important, and the question arises as to whether or not the cross section used in the foregoing tests is representative of standard practice. The columns were made of hat sections containing, after fabrication, eight rounds, four at the neutral axis and two at each of both extreme fibers. The significant rounds are those at the extremities because they have more influence on column stability than those at the neutral axis. In our experience in stainless steel design, there are few structural members that contain less than two bends in the extreme fibers. In this respect, the cross section used is representative of standard practice.

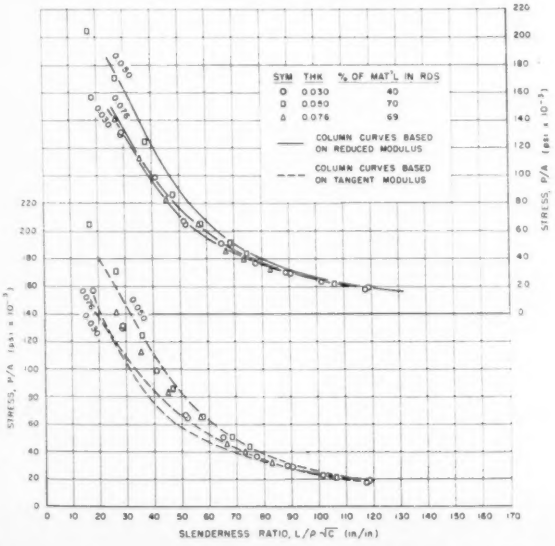
SYM THK % OF MAT'L IN RDS
0.030 40
0.050 70
0.076 69
COLUMN CURVES BASED ON REDUCED MODULUS
COLUMN CURVES BASED ON TANGENT MODULUS
STRESS, P/A (psi x 10⁻³)
SLENDERNESS RATIO, L/ρ√c (in/in)

FIG. 10. Comparison of test data with tangent and reduced modulus column curves, full-hard longitudinal.

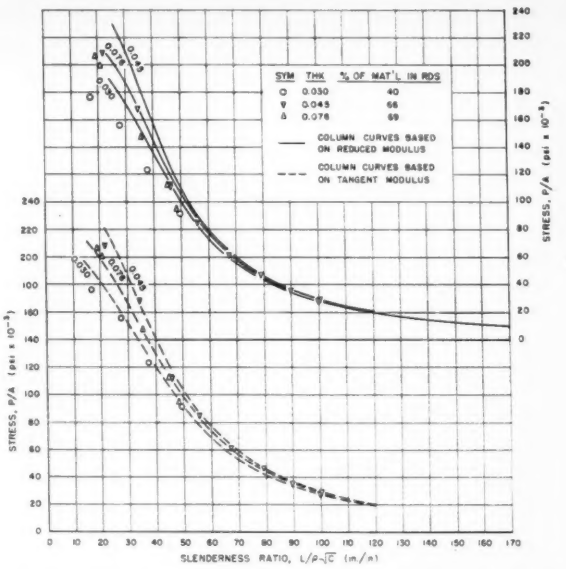
SYM THK % OF MAT'L IN RDS
0.030 40
0.045 66
0.076 69
COLUMN CURVES BASED ON REDUCED MODULUS
COLUMN CURVES BASED ON TANGENT MODULUS
STRESS, P/A (psi x 10⁻³)
SLENDERNESS RATIO, L/ρ√c (in/in)

FIG. 11. Comparison of test data with tangent and reduced modulus column curves, full-hard transverse.

Except in unusual cases, it is probably conservative, too. The test specimens, made so that the cross sections were as stable as possible, have between 37 and 70 per cent of the total material in the rounds (except for annealed specimens, which had less). However, good design practice will demand stable cross sections for critical structures, so that the percentage of round material should not often be less than that cited.

Column Curves

The tests reported herein show that, for all practical purposes, column curves based upon the reduced modulus agree with test data for the $^1/_4$-, $^1/_2$-, and full-hard longitudinal specimens in slenderness ratios less than 110. On the other hand, for $^1/_4$-, $^1/_2$-, and full-hard transverse specimens, the tests show that the test data agreed with the column curves based on the tangent modulus. It was further demonstrated that the agreement of the longitudinal test data with the reduced modulus column curves is due to the increased hardness—and therefore the increased load capacity—of the material in the rounds due to forming rather than to the behavior of the column according to the theory of the reduced modulus. In the slenderness ratios above 110, the reduced modulus column curves are slightly higher than the test data in the $^1/_4$- and $^1/_2$-hard material for both transverse and longitudinal grain.

Column Curves for Design Specifications

The ultimate purpose of the research reported herein is to prepare column design curves for a stainless steel design specification. Thus, while design curves have not yet been prepared, it is suggested that allowable column curves for $^1/_4$-, $^1/_2$-, and full-hard material be based upon the reduced modulus for the grain in the longitudinal direction and upon the tangent modulus

(*Continued on page 48*)

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A study directed toward aircraft designed to carry passengers or cargo over medium ranges, giving computations for the power required by each type of plane.

The Comparative Performance of Helicopters, Convertiplanes, and Slow-Flying Airplanes

Introduction

The public acceptance of any salable article can be determined only by tests. Assuming an ability to pay, acceptance may depend as much upon appeal to the senses as upon any economic advantage that can be shown in numbers. High-speed airplanes have a strong appeal, and so do helicopters that can hover. Autogiros, airships, and commercial transport flying boats seem to lack popular appeal, and to date they have been difficult to sell even though the numbers are often in their favor.

Whether the current attraction and enthusiasm for convertiplanes is brought on by their mysterious nature, by imagined uses, by some overpowering sales promotion, or just by a healthy innate curiosity makes little difference—the desire to try them out must be satisfied. But some place along the line, somebody is going to have to show realistic numbers upon which prospective operators can formulate plans. A study of the weights and performances of convertiplanes was therefore made, based upon the applicable experience with related aircraft, in an attempt to show what can reasonably be expected of transport aircraft in the convertiplane category.

This paper presents the results of the study showing the comparative performances of three types of aircraft—a helicopter, a convertiplane, and a fixed-wing airplane designed especially for operation from restricted areas. The study is limited to aircraft designed for carrying passengers and cargo over medium ranges, that being the only field in which the three are directly competitive. This rules out rotorcycles and crane-type helicopters on one end of the spectrum and high-performance vertical take-off fighters on the other end. A representative aircraft was designed for each of the three types. In addition, performances and weights for transport airplanes were generalized, and a fourth aircraft referred to as an "average transport airplane," was designed reduced to a size that would carry the same load as the other three. The weights and performances for the four aircraft are then compared.

Time for the Comparison

For the sake of consistency, the helicopter to be used for the comparison will be one having the best performance characteristics that can be anticipated at the time all four could be available. It is presumed that with reasonable effort all four could be operational in 6 years. The helicopter performances shown herein, therefore, are better than any that have been measured on service helicopters to date.

It is anticipated that geared gas turbines will be available and used, at least in all short-range, low-altitude aircraft during the period under consideration. Gas turbines are therefore specified, but sizes are not selected. For this preliminary study, it is more convenient to use "rubber" engines and leave the problem of selection of the number and size of engines until the time for the design for a specific mission or operation.

Description of the Aircraft

If convertiplanes had not been conceived, there would be good reason to attempt to reach higher and higher speeds with helicopters, even sometimes at the expense of usefulness at the lower speeds. Similarly, if we did not have helicopters, it would be worth while to develop and perfect means for extending the operational speeds of fixed-wing airplanes down to zero. But since we can have convertiplanes of several types, there is no reason for ruining a good prospective helicopter design by trying to have it go so fast that convertiplanes will not be necessary. Neither is it wise in commercial air transportation to try to make a low-powered fixed-wing airplane hover when we can develop a convertiplane to do the job. Therefore, it seems that it would be more meaningful in this study to design one of each type that would be completely representative of its own type and then compare the respective abilities of each plane to transport people and goods. The pay load and the

* Head, Rotary Wing Aircraft Design.

fixed load can be the same for all four; but the speeds and ranges will be selected arbitrarily to be those most suitable to the type.

Each aircraft is to carry a pay load of 4,000 lbs., about equivalent to 20 passengers and their baggage. The fixed load—made up of crew, communications equipment, instruments, and furnishings—will be 2,870 lbs. for each aircraft. The helicopter is designed for an operational range of 100 nautical miles at a cruising speed of 100 knots. The rotor arrangement is not specified at this time since this study is concerned not with the differences between types of helicopters but with helicopters as a category of aircraft. The estimates are based upon what is thought to be the best that can be done with any helicopter design, and the basis for the estimates will be shown later in the paper. The helicopter will have more than one engine, and the engines will be so selected and controlled that, in case of a failure of one power plant, the helicopter can continue a vertical climb on the remaining engines, without interruption. The helicopter can therefore operate with comparative safety without runways.

For purposes of weight and performance estimation a specific type of convertiplane must be selected. The author does not intend here either to attack or to defend any type but only to estimate the weight and performance of a representative convertiplane. The type of convertiplane selected is the one having tilting rotors at the wing tips. The justification for this selection is at least as sound as the selection by a college class of the "Senior most likely to succeed," and the time required to ascertain the wisdom of the choice is about the same. Like the helicopter, the power plants will be adequate to permit operation with comparative safety from a small heliport without runways.

Preliminary studies indicate clearly that for a convertiplane to pay off it would have to be appreciably faster and more efficient than a helicopter. The design operating range and cruising speed for the convertiplane are therefore established at 200 nautical miles and 200 knots, respectively.

Now for the fixed-wing airplane we have to agree on how slow is slow. As the minimum flying speed of a fixed-wing airplane approaches zero, the aircraft becomes in a sense another form of helicopter or convertiplane; and, if neither of these latter categories of aircraft were in existence, it would be worth while to develop hovering airplanes for transportation in the 75 to 250 knot cruising speed range. At higher speeds the feasibility of the vertical take-off airplane has already been demonstrated. But when greater load-carrying ability is desired and a high cruising speed becomes less important, the advantages of the VTO as a type become obscure. A hovering airplane that would be in competition with a helicopter or a convertiplane as a transport aircraft must have excellent control down to its minimum operation speed—with power on in any case and, for transport operation, even with power off—and must possess structural and aerodynamic efficiency comparable to that of a convertiplane having a cyclically controlled rotor. This does not appear possible at this time.

For some small-scale commercial operations or for many wartime operations, long runways are obviously out of the question. On the other hand, a 200 by 400 ft. area is considered about right for a heliport. The Air Force helicopter training heliport near Williamsburg, Va., is 600 ft. square. A runway of 1,500 ft. was at one time considered by some people to be acceptable from the safety standpoint for the use of a large helicopter. It seems that some heliports would be satisfactory for the operation of certain fixed-wing airplanes.

A runway of reasonable length would not be an intolerable requirement for a busy terminal; it all depends upon how much traffic there is. If a city (like Trenton, for instance, which does not have a municipal airport) can afford a four-lane highway all the way through the city, it should be able to raise money for a two-block long runway along the river bank. It must be acknowledged also that, unless the contemplated airplane can use a runway which is only a small fraction of the length of those common to large municipal airports, there would be no point in constructing another close-in airport.

With these factors in mind, a slow-flying airplane is arbitrarily defined as one that can operate safely from a 1,000-ft. runway. Whether it uses powerful flaps, boundary-layer control, supercirculation, engines of extraordinarily high horsepower, extra large propellers, or any combination of these things is left entirely up to the designer. It is the author's purpose to predict the weight and performance of the airplane having the best combination of these features.

Source of Data for the Estimates

The weights of a large number of helicopters have been tabulated by components, and the weights of each component as a per cent of design gross weight are shown in Fig. 1. The manner of segregation of weight items is somewhat different from that used for other purposes, and the grouping of the detail weight items is shown in Table 1. The fuel and oil tanks, for instance, are included in the combustible load because their weights vary with fuel and oil quantity; fixed equipment is distributed between the components in which it is installed, etc.

The wing loadings and power loadings vary with size, as well as with the purpose of the helicopter. The general trends of the loadings and of the weight per square foot of rotor projected area are shown as solid lines in Fig. 2. The dotted lines extending to the right of the chart show the unit loadings and weights for special-purpose military helicopters and for helicopters intended primarily for carrying cargo at typical helicopter speeds. It is the author's belief that for the most economical operation, to provide adequate safety, and to keep noise to a minimum the rotor disc loadings for large load carrying helicopters will not exceed the values shown by the long-dashed lines—about 6 lbs. per sq.ft.

TABLE 1
Division of Weight Items into Components

Fixed load	Transmission system
Instruments	Gear boxes
Communications	Drives
Furnishings	Oil system
Crew	Oil
Miscellaneous	
Pay load	Propeller
Passengers	Propeller
Baggage	Propeller controls
Cargo	
Combustible load	Wing and tail
Fuel	Wing
Oil (engine)	Tail
Fuel and oil tanks	Controls
	Actuators
Power plant	Rotor(s)
Engine	Blades
Engine accessories	Hub
Engine controls	Pylon
Engine starter	Controls
Engine cowling	Actuators
Fuel and oil systems (less tanks)	
	Other structures
	Body
	Nacelle(s)
	Landing gear
	Helicopter tail(s)
	Actuators

The performance data for helicopters are taken from flight tests and reduced to a common basis. The engine power required curves are shown on Fig. 3. Power required at speeds at which the blade tips stall is not included in this chart because this speed would not ordinarily be within the range selected for cruising. Although the present study is concerned only with transport-type helicopters, the upper limit for the smaller training helicopters is drawn on the same chart to show the wide difference between the two extremes of aerodynamic efficiency.

Performance and weight data for fixed-wing transport airplanes were set up in a similar manner. Airplane weights are more readily available than helicopter weights, and they are not shown here. The performance in terms of engine horsepower required at various speeds can be prepared in a manner similar to that used for helicopters. These curves are shown in Fig. 4. Although the limits for a large number of airplanes seem fairly narrow, they were found to be inapplicable to estimation of the power required for slow-flying clean airplanes. These curves were used for estimating only the power required for the average transport airplane, and the power required for the slow-flying airplane was calculated independently.

ESTIMATION OF WEIGHTS

The component weights in per cent of design gross weight for the three aircraft as now defined are shown in Table 2. To get a quicker grasp of the weight comparisons, the same information is shown graphically in Fig. 5. (The differences in range should always be borne in mind.) Also shown are the weights of the components of the average transport airplane of the type now in general use, except that it has geared gas turbines instead of piston engines. The weight percentages of the structural components of the average transport are the averages for a number of transport aircraft now in use.

For the four aircraft types to be designed, the average weight of geared gas turbines complete with accessories, starter, etc., is estimated to be 0.5 lbs. per take-off horsepower as compared to 1.3 lbs. per horsepower for piston engines in the larger sizes. It is estimated that the average specific fuel consumption for gas turbines will be 20 per cent higher than for present-day piston engines.

Several of the component weights in the table warrant some explanation. The weight of the convertiplane wing is almost the same as that of the transport wing, whereas one usually assumes a convertiplane wing will be extremely small. Transport airplanes have a flaps-up stalling speed of about 100 knots. The conversion speed for the first generation of tilting rotor convertiplanes will be about the same—and the wing loading will therefore be about the same. An airplane wing is complicated structurally by high lift flaps and their controls which the convertiplane can do without. The convertiplane wing, on the other hand, is subject to high torsional and vibratory stresses that will require some strength margins. The weights are therefore about equal.

The helicopter component weights shown are for a tandem rotor machine. Had the weights of a single rotor helicopter been used, the transmission weights would have been lower, and the rotor weights would have been higher.

Each gross weight should be considered in light of the speed and the range of the aircraft to understand the relationships between the types. It is not difficult to

TABLE 2
Component Weights in Per Cent of Gross Weight

	Helicopter	Convertiplane	Slow-Flying Airplane	Average Transport
Pay load, lbs.	4,000	4,000	4,000	4,000
Fixed load, lbs.	2,870	2,870	2,870	2,870
Combustible, %	6.5	6.6	9.3	21.9
Power plant, %	6.9	8.1	9.9	7.8
Transmission, %	10.5	12.0	...	...
Propeller, %	...	...	3.0	2.7
Wing and tail, %	...	12.0	17.3	12.5
Rotor group, %	14.0	10.5	...	..
Other structures, %	20.0	18.2	21.8	20.3
Gross weight (less load), %	57.9	67.4	61.3	65.2
Load, %	42.1	32.6	38.7	34.8
Gross weight, lbs.	16,300	21,100	17,750	19,750
Weight empty, lbs.	10,225	14,750	11,150	10,700
Useful load, %	37.3	30.0	37.2	45.8
Take-off power, hp.	2,250	3,420	3,520	3,080
Range, nautical miles	100	200	200	600
Cruising speed, knots	100	200	200	240

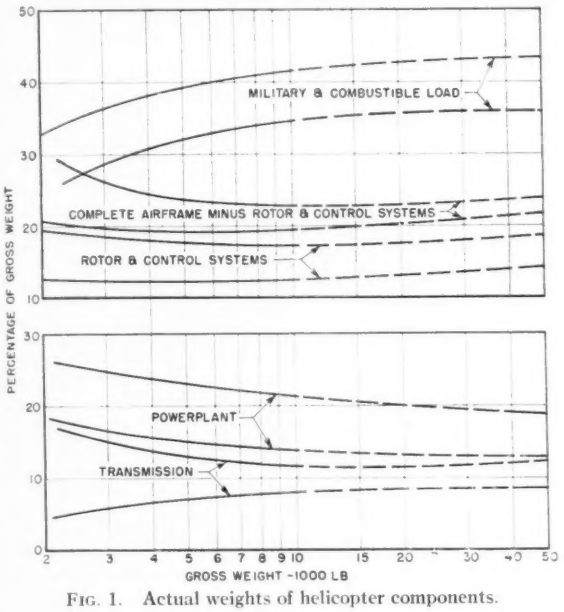

FIG. 1. Actual weights of helicopter components.

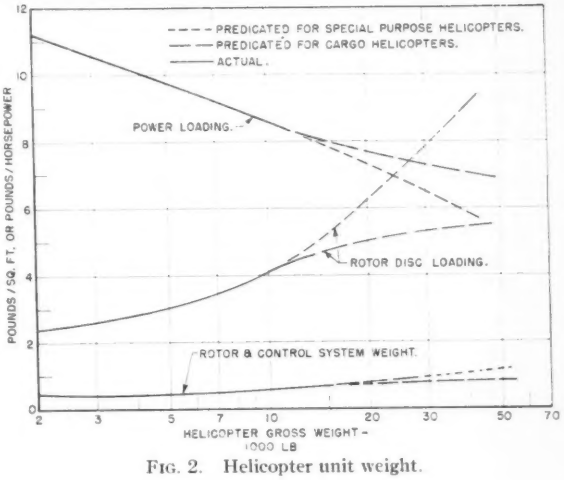
PREDICATED FOR SPECIAL PURPOSE HELICOPTERS.
PREDICATED FOR CARGO HELICOPTERS.
ACTUAL.
POWER LOADING.
ROTOR DISC LOADING.
ROTOR & CONTROL SYSTEM WEIGHT.
POUNDS / SQ. FT. OR POUNDS / HORSEPOWER
HELICOPTER GROSS WEIGHT - 1000 LB

FIG. 2. Helicopter unit weight.

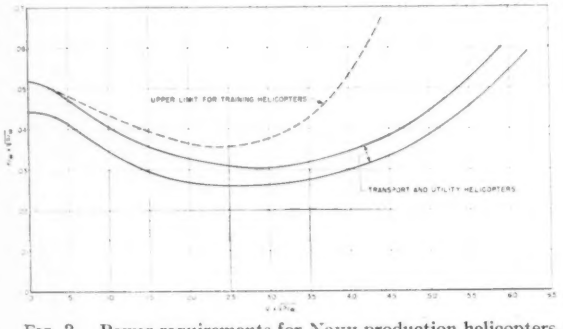

FIG. 3. Power requirements for Navy production helicopters, 1,500 ft. altitude. No tip stall. P = brake horsepower at engine; V = speed in knots; W = gross weight, lbs.; S = projected disc area, sq.ft.

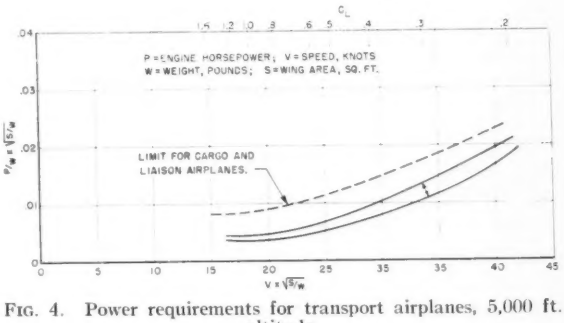

FIG. 4. Power requirements for transport airplanes, 5,000 ft. altitude.

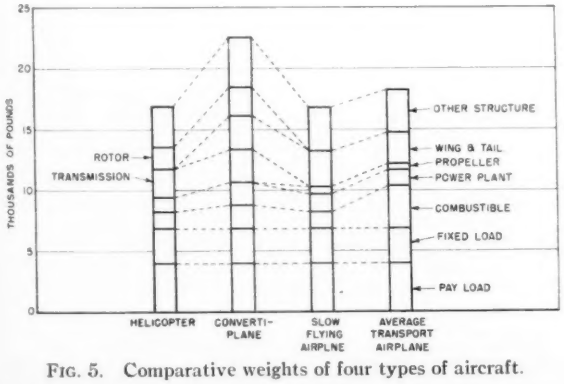

FIG. 5. Comparative weights of four types of aircraft.

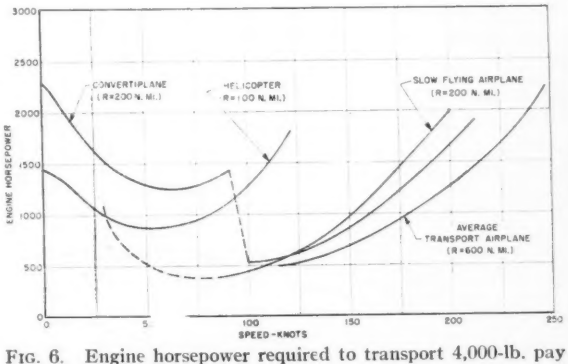
CONVERTIPLANE (R=200 N. MI.)
HELICOPTER (R=100 N. MI.)
SLOW FLYING AIRPLANE (R=200 N. MI.)
AVERAGE TRANSPORT AIRPLANE (R=600 N. MI.)
ENGINE HORSEPOWER
SPEED - KNOTS

FIG. 6. Engine horsepower required to transport 4,000-lb. pay load.

compute, for instance, that, if the average transport airplane's design range were to be reduced from 600 to 200 nautical miles to make it equal to that of the convertiplane and the slow-flying airplane, gross weight of the fixed-wing airplane would be reduced from 19,750 to 14,000 lbs.

In a similar manner, if the fuel load in the helicopter were to be doubled to increase its range from 100 to 200 nautical miles, its design gross weight would be increased from 16,300 to 19,150 lbs., and its weight empty would be increased from 10,225 to 12,740 lbs. It follows then that, if a convertiplane were to be substituted for a helicopter being used in a 200 nautical mile operation, the weight empty of the aircraft used would increase from 12,740 to 14,750 lbs. or 16 per cent, the fuel used per trip would be reduced from 296 to 167 gal. or 43 per cent, and the flight time would be cut in half.

The weight estimates cannot be made without knowledge of powers required, at least at the take-off and cruise conditions. The preliminary computations were made on a unit aircraft weight basis. After the gross weights were determined, final computations of powers required were performed. The results for the four aircraft carrying the same load are shown in Fig. 6. The computed powers are shown as solid lines. The connecting dashed lines are pure guesses, the powers to depend upon the features of the design and the flight techniques used.

Conclusion

The author has presented generalized data on the performance and component weights of current helicopter designs and has combined this with fixed-wing airplane data to provide a basis for the estimation of the performance and component weights of a representative convertiplane. The figures show that the convertiplane has a substantial advantage over the helicopter when operating as a passenger vehicle at a 200 nautical mile range. Its primary advantages over a slow-flying airplane are that no runways will be required for it and that it will have more positive control at low speeds. From the standpoint of performance and simplicity, the advantages of a convertiplane over a slow-flying airplane are not overpowering.

Although this paper is concerned with the comparative performances of three categories of aircraft, it does not follow naturally that the three are in direct competition with one another. Nor need it matter particularly whether or not the convertiplane should be less efficient structurally than the other types. The convertiplane can perform missions that the other types are altogether incapable of performing. Its uses will be unique—and not competitive with other aircraft.

In the first helicopter forum, held in the Franklin Institute in Philadelphia in 1937, it was pointed out that the helicopter was so much less efficient than the airplane that it would find but little application. This author then pointed out that the helicopter should not be considered to be in competition with the airplane but that other new uses should be found for it and that every motorcycle-side car combination in use in World War I should be replaced with a helicopter in the next war. Well, in World War II the jeep came along and replaced not only the Harley-Davidsons but also many of the Dodges and Cadillacs. Maybe the next war, if any, will find courier helicopters or "rotorcycles" in use. But, in spite of a performance less than predicted, so many uses have been found for helicopters that we would strongly dislike having to get along without them. And some of the most important of these uses were not conceived until after helicopters had been developed.

There will be many uses for convertiplanes, though it may be difficult to predict in advance what those uses will be. But at least one unique mission will be predicted now: A convertiplane can be attached to a large long-range airplane and flown to a place which has no landing field of any kind. The convertiplane could detach itself, extend and start its rotor, perform its duty near the ground or water, stop and retract its rotor, and attach itself to the airplane again. This operation could be performed as many times as necessary to transfer goods or people between the airplane and the ground. A convertiplane that can do this will be quite complicated and a long time in development, yet it is something to look forward to while we concentrate first on simpler designs. For the near future, there is always a place for a vehicle that can move at high speeds and carry a load from one obscure place to another. If someone has a good one it will be used.

Fiber Metallurgy—Its Use for Slip Ring Brushes

(*Continued from page 32*)

were explored with brush currents up to 1 amp. In all cases, low noise levels were maintained. Noise voltage and wear showed negligible change on testing under conditions simulating altitudes of 50,000 ft.

Certainly all the conditions for optimum performance of fiber metal brushes have not been determined. This article serves to bring this development to the attention of the aircraft industry.

The failure of the Comets explained in terms of fuselage shell brittleness and an indication of the need to replace the tensile theory of the strength of materials with a new criterion.

On the Danger of Combined Stresses in Pressurized Structures

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Introduction

Many theories have been advanced to explain the recent catastrophic explosions of the British Comets. In none of these, however, has the correlation between pattern of stresses and the fundamental properties of materials played a decisive role. It is the purpose of this paper to investigate the pertinence of this most important relationship to the case of the Comet explosions and to point out the general applicability of the principles involved.

Fatigue of the fuselage material was the earliest explanation to be advanced by the British engineers. But the number of cycles of variable load was hardly sufficient to produce the phenomenon known as fatigue. This consideration led some American engineers to believe that the cause of failure was insufficient design thickness of the Comet's fuselage wall. Yet, it is inconceivable that the de Havilland engineers failed to employ modern methods of pressure vessel analysis. Undoubtedly, they took into account not only the principal stresses but also those produced by discontinuities at heads and openings and the shearing, bending, and torsional stresses produced by wings and control surfaces. In this analysis, however, they had to use the usual theories of failure. Even when using the most suitable theory, it is always possible to underestimate the load carrying capacity of a structure for a reason which will soon be apparent.

An Inadequacy of the Usual Theories of Failure

The purpose of a theory of failure is to make possible the application of tensile test data to cases of combined stresses. But the tensile strength is not an elementary or simple property of a material. The ductile metal being tested in tension first deforms elastically, then elastoplastically, and only then, plastically, forming a neck. Finally, it breaks in a brittle manner. Nothing like this ever happens in the case of a pressurized vessel because in this case even ductile materials deform extremely little plastically and do not form any necks. Thus, the tensile strength of ductile materials involves a rather special case of deformation.

When a body is subjected to the action of any combination of stresses these stresses may be reduced to two kinds—namely, tangential and normal. The ratio of these stresses remains approximately constant, independent of the magnitude of loading for each type of stressing whether it be tension, compression, or combined stresses as in the case of pressure vessels. These stresses are opposed by two corresponding resistances of the material—resistance to slip or shearing and resistance to tearing apart or cohesive strength. Thus tensile strength is not an elementary measure of strength but a complex resistance consisting of two strengths. Each material in each physical state possesses these two properties in a definite ratio, but this ratio is not revealed by the ordinary tension tests. Failure occurs when one type of stress overcomes the corresponding resistance of the material, and the type of failure depends upon which of the two resistances is overcome first. If the normal stress overcomes the cohesive resistance first the fracture is of a brittle type, and if shearing strength is overcome first the fracture will be ductile—i.e., accompanied by appreciable deformation prior to fracture.

Since tensile strength is composed of two strengths in unknown proportion and since the tensile failure is phenomenologically different from failure under combined stresses, tensile strength data cannot be applied with certainty to cases of combined stresses.

This explains why, even if a particular theory seems best suited for a certain material, it often fails to predict not only the type of a fracture but also the magnitude of the load carrying capacity of a structure subjected to combined stresses without recourse to the unreliable theories of failure. Unfortunately, so far as is known to the author, none of our research institutions has been interested in obtaining this important design data, although there is no difficulty in obtaining it.

The Determination of Cohesive and Shearing Strengths

To determine the cohesive strength we use a notched specimen and the ordinary tensile test procedure. If a notch is not sufficient to produce a brittle fracture we may cool the specimen or use a high strain rate. From

* Research Engineer.

such data we may easily calculate the cohesive strength of a material, using a theory of stress concentration such as Neuber's.

Shearing strength may be determined with sufficient accuracy from the torsion testing of thin tubes.

Having these two values for a material, we may now determine its propensity for brittleness or plasticity. If slip res./cohes. res. $= t/s > 1$, the material is brittle under the given conditions. If this ratio is less than one, the material is ductile. If the ratio of tangential stress (τ) to normal stress (σ) is greater than one ($\tau/\sigma > 1$), the combined stress tends to produce ductile fracture, and if this ratio is less than one ($\tau/\sigma < 1$), the tendency is to produce a brittle fracture.

Thus, like materials, stresses may be "hard" or "soft," and the kind of fracture depends upon the relationship between the two ratios τ/σ and t/s. When $\tau/\sigma > t/s$, we have the ductile fracture of soft material. When $\tau/\sigma < t/s$, we have brittleness and a tearing-off fracture. It is important to note that the character of the fracture does not depend upon the value of any of these quantities but only on their ratios.

There is no doubt that at the moment of the explosion, the Comet's fuselage material was in a brittle state. There is also no doubt that the designers used a material which is ductile under ordinary conditions of test. Hence, we conclude that the material was hardened as a result of a combination of stresses.

Example

To illustrate our theory let us consider, as an example, aluminum alloy 7075S-T6. This is a rather ductile material, but a tank made of this alloy and subjected to an internal pressure bursts into small fragments because in this case we have $\tau/\sigma < t/s$.

Visualization of the relationships involved here is facilitated by the use of a figure (see Fig. 1). If we plot the ratio τ/σ against the ratio t/s, the line $\tau/\sigma = t/s$ divides the quadrant into two areas. Any point in the upper area corresponds to the ductile state, and a point in the lower area corresponds to the brittle state.

For SAE 1045 steel the ratio t/s is approximately 0.36. For tension the ratio τ/σ is 0.5 so that the point N_1 with these coordinates is in the ductile field. In the case of a pressure vessel, however, τ/σ is about 0.29 so that the point characterizing our material in this state would be in the brittle field. Consequently, this material will have a brittle fracture if used for a pressure vessel, and we will see that such materials are unsafe for this application. On the other hand, if we use normalized SAE 1045 steel, for which $t/s = 0.23$, the corresponding point N_3 would be in the ductile field so that this steel might be used for a tank under pressure.

For design purposes, the diagram of Fig. 2 is more useful if we have the necessary data. It may be called the diagram of mechanical state. Cohesive strength and normal stresses are plotted as abscissas, while shearing strength and tangential stresses are plotted as ordinates. Since, for a given configuration, the ratio of tangential stress to normal stress may be taken as constant, independent of the magnitude of loading, this relationship may be represented by a straight line through the origin with slope equal to τ/σ. The diagram permits us to predict not only the type of fracture when the structure is overloaded but also the maximum permissible load.

As an example, we have the following data for SAE 1045 steel:

Cohesive strength 256,000 lbs. per sq.in. in 10 per cent cold worked state

Cohesive strength 190,000 lbs. per sq.in. in normalized state

Shearing strength 94,000 lbs. per sq.in. in 10 per cent cold worked state

Shearing strength 42,000 lbs. per sq.in. in normalized state

From the diagram we again see, since the stress line intersects the cohesive strength line, that cold rolled SAE 1045 will have a brittle fracture and is, therefore, unsuitable for the job. But, normalized SAE 1045 steel will fracture in the ductile state (as is seen from the diagram) and may, therefore, be safely used for a tank.

For comparison, the stress line for tension ($\tau/\sigma = {}^1/_2$) is drawn in the same diagram. We see that, in tension, both states of steel are ductile.

Material in the Brittle State Is Not Safe

There is always a temptation to use material heat treated or cold rolled for higher tensile strength, entirely forgetting that a material which is strongest under one pattern of stresses is not necessarily strongest under another pattern of stresses. In connection with the above example, we are naturally led to ask if a given vessel would be lighter if made from the 10 per cent cold rolled rather than the normalized steel. The answer is that, since normalized steel remains ductile under conditions of pressure vessel loading, a smaller factor of safety may be allowed than in the case of the cold rolled steel. Consequently, the weight may be the same in both cases, but the reliability of a ductile structure will always be higher.

There are several reasons why material in the brittle state is unreliable and may even be dangerous:

(1) The strength of a brittle material is unpredictable because the smallest internal defects may start a dangerous crack. It is known that even in the case of standard tensile tests the variance of experimental results is much greater in cases of brittle than in cases of ductile materials.

(2) Brittle materials break suddenly, while ductile materials give some warning by excessive deformation.

(3) Materials in the brittle state are sensitive to shocks and vibrations.

(4) The stress concentrations, unavoidable in any design, are much more dangerous in brittle materials because they have insufficient plasticity to deform and redistribute the stresses.

(5) The effect of size is much more pronounced in the brittle state. . . . Thin walled brittle elements are the most dangerous under load and dynamic conditions.

(6) Destructive vibrations are not damped as efficiently in the brittle as in the ductile state.

(7) The transition temperature from ductile to brittle state is higher when the stress pattern is of the type we have called "hard." Lowering of the temperature may become the final factor in a brittle failure, occurring earlier in the brittle state than in the ductile.

(8) The efficiency of welded joints is greater in ductile than in brittle material. This is important not only from the standpoint of safety but also from that of minimum weight.

No vessel can be made with absolute geometrical precision. It may be slightly elliptical or have local irregularities of shape, curvature, etc. This tends to create stress gradients and local stresses. If the material is sufficiently ductile, these irregularities tend to diminish and may even disappear. But, if the material is brittle, additional stresses will develop.

(9) Finally, we come to what is perhaps the most serious objection to using material in the brittle state for the construction of pressure vessels. The energy accumulated in the structure plus that of the compressed air is suddenly released, producing an explosion-like decompression of the shell. If the material were in the ductile state, a local deformation might give a warning, and, if a rupture occurred, the decompression would be gradual.

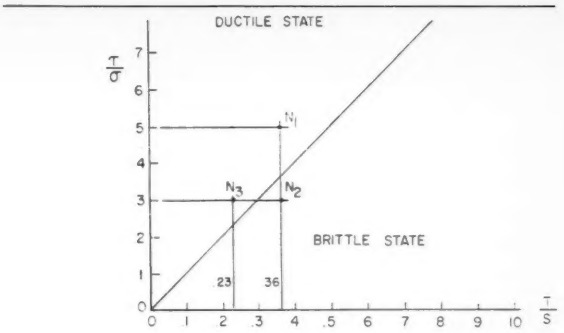

FIG. 1

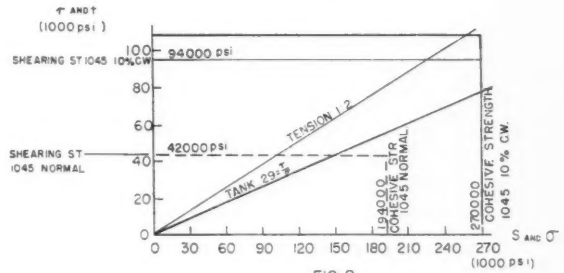

FIG. 2

FIG. 3

The Need for Basic Research

It is important to note that the described method of approach is only the beginning of a solution to the problem. This is due to the lack of sufficient investigation of the various factors affecting shear and cohesive resistance. For instance, our straight line which characterizes the state of stress is no longer a line in the plastic state except in the simplest cases. As a rule, the change from elastic to plastic state involves some redistribution of stresses, and deformations will cause some bending of our line. Cohesive resistance is practically independent of the state of stress, but it does depend on the preliminary strain hardening. In addition to this, the diagram of mechanical state applies to a uniform stress distribution so that, in cases of nonuniform stress distribution, we would have to deal with averages until more sophisticated methods are developed.

Not long ago it was believed that brittleness and ductility are inherent properties of individual materials. Only recently was it found that they are only states of matter and that any material may be brittle or ductile not only according to its temperature but also according to its speed of loading and pattern of stresses. At the same time it was found that tensile strength is not a simple unique property which determines the behavior of a material under combined stresses. It is a complex property which must be resolved into its elementary components in order to be a useful tool in design.

The old picture of strength not only prevented the development of the general theory of the resistance of materials but made impossible a clear understanding of the behavior of metals and the phenomena accompanying it, as, for instance, the effect of the speed of deformation, effects of heat and cold (transition temperature), fatigue phenomena (plain and combined), hardness, strain hardening, impact, etc.

What May the Design Engineer Do Until Adequate Data and Theories Are Available?

The necessity for further fundamental research on the nature of the strength of metals is obvious. Only when the puzzle of tensile strength is solved by resolving it into two strengths—shearing and cohesive—will the mystery of explosions of pressurized shells be solved. Only then will the design of all kinds of shell structures be on as firm a foundation as the design of truss structural elements is now. But what can we do now in the absence of these fundamental facts on the strength of materials?

First, we may select materials for pressure vessels by comparison. A material which is strongest in static tensile tests of a notched specimen will be more suitable for application in cases of combined stresses. It will, in general, be found that the best material in a regular tensile test will not be the best when tested in notched condition.

It is well known that, while in most cases a notch reduces the strength, there are also cases in which it increases the strength. Such are the cases of ductile materials. Enlightening results were obtained using the specimen shown in Fig. 3. In the specimen, the

diameter at the root of the notch is equal to the diameter of the smooth part. Using this specimen, it is possible to classify materials into two groups accordingly as they break at the notch or at the smooth part. The latter will be found to be more suitable for combined loading.

However, really reliable data for combined stress design can be obtained only by the determination of shearing and cohesive strengths as was described before. The investigation and determination of these properties is one of the most urgent problems of modern material engineering.

The Comet catastrophe caused great concern among engineers and even the general public, especially in England. It was a lesson to all of us on a big scale, a lesson which we should study because similar accidents on a much smaller scale are of quite frequent occurrence. We are in general need of better design methods, better calculation methods, and better selection of materials for all types of pressurized vessels. Never before has the problem of designing pressurized structures occupied the attention of engineers so much as it does now both because of the increased use of such structures and because of the high pressures used now.

Suggestions have been made to modify the stress pattern by the use of additional structural elements, but the shell design will always be the lightest and strongest structural form, provided the proper materials and methods of calculation are employed.

Although it seems certain that the above considerations explain the principal cause of the failure of pressurized structures, new factors do come into play when a statically indeterminate structure is subjected to the effects of a fluctuating load. These factors include residual stresses and the phenomenon know as "incremental collapse." This phenomenon, in contrast to fatigue, does not require many fluctuations of the load to produce failure.

Conclusion

The fact that the failure of the Comets occurred in an explosive manner indicates that the fuselage shell was in the brittle state. Since a normally ductile material was undoubtedly used for its construction, this brittle failure is evidently the result of an unfavorable combination of stresses.

Materials in the brittle state are unreliable and dangerous for many reasons. Therefore, it is important for safe design to avoid this condition. The usual theories of failure, which are the only tools of the stress analyst in this case, give no information about brittleness or ductility which results from a combination of stresses. These theories make use of tensile strength for the calculation of the strength of structures subjected to combined stresses. Because the tensile deformation of the ductile materials is different from the deformation of structures under combined stresses, the predictions of the theories of failure are often in error.

Thus the problem of the Comets is a general one in which all designers of pressurized structures should be interested. The unprecedented increase of the use of such structures and the rapid growth of applied pressures make finding a safe method of design an important and urgent problem.

A logical solution to the problem might rest on determining the cohesive and shear strengths of each material under consideration. We have seen how the character of failure and the magnitude of collapse loading may be determined without recourse to the theories of failure.

Thus we have seen that a new criterion of strength is needed to replace tensile strength which is unsuitable in this case. The design engineers are conscious of this necessity but cannot do much until material engineers provide the necessary data.

Column Curves for Type 301 Stainless Steel

(*Continued from page 39*)

for the grain in the transverse direction. However, it must be remembered that this use of the reduced modulus is only a "gimmick" to account for the increased load capacity of a column due to forming the rounds. Typical stress-strain curves for the 1/4-, 1/2-, and full-hard material in both grain directions, upon which the design column curves are based, must also be given. The criterion for the use of the column curves will be that the stress-strain curve of the stainless steel to be used must have a slope equal to or greater than the typical stress-strain curves.

For annealed material it is suggested that the tangent modulus be used in preparing allowable column curves for slenderness ratios over 70. For lower slenderness ratios, column curves based upon the reduced modulus should be used, although actual loads will be appreciably greater than those predicted.

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Effects of Boundary-Layer Control System Efficiency on Performance

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An energy-method evaluation of independent and integrated boundary-layer control systems as they affect climb, take-off, and range.

Symbols

BLC = boundary-layer control
C_Q = boundary-layer control volume coefficient Q/SV
D = drag
D_0 = drag, without effect of BLC
E = energy
g = acceleration of gravity
H = heat value of fuel
h = height
KE = kinetic energy
K_d = aerodynamic characteristic factor for effectiveness of BLC in reducing drag power
K_L = aerodynamic characteristic factor for effectiveness of BLC in increasing lift
L = lift
L_0 = lift, without effect of BLC
p = propulsive system
PE = potential energy
Q = volume of air pumped by BLC system
${}_1Q_2$ = heat added during thermodynamic process
R = range
T = thrust
T_0 = thrust of engine without BLC requirement
t = time
V = velocity
${}_1W_{m_2}$ = mechanical work performed during thermodynamic process
W_f = weight of fuel
W_0 = initial weight of airplane
W_1 = final weight of airplane
x = fraction of engine output lost because of operation of BLC
η_e = engine efficiency = shaft work/fuel energy
η_P = propulsive efficiency (independent system)
η_{prop} = propeller efficiency
η_{BLC} = BLC system efficiency = input power/air horsepower
ζ_1 = η_{BLC}/η_P
ζ_2 = $(dW_{fBLC}/dt)/(dW_{fp}/dt)$

Introduction

An approach to the evaluation of the effect of boundary-layer control system efficiency on climb, take-off acceleration, and range is presented, utilizing the energy concept. The results are not directly applicable to a particular aircraft without prior knowledge of the individual characteristic boundary-layer control effects on lift and drag, as will be pointed out. They do, however, enable visualization of the effect of the efficiency of the pumping system—i.e., its capacity to convert fuel energy into work on the boundary-layer air or system input horsepower into air horsepower.

The derivations presented are for the most part applicable to the airplane with independent boundary-layer control system. The energy equation is also arranged in form suitable for dealing with the "integrated" system, wherein energy for boundary-layer control is drawn from the main engine, with consequent reduction of the useful work derived from engine thrust.

Energy Equations for BLC Aircraft

The general energy equation for any aircraft may be written between two states (1) and (2)

$$KE_1 + PE_1 + {}_1Q_2 = KE_2 + PE_2 + {}_1W_{m_2}$$

or

$$(WV_1^2/2g) + Wh_1 + {}_1Q_2 = (WV_2^2/2g) + Wh_2 + {}_1W_{m_2}$$

In time-derivative form this becomes

$$-\frac{WV}{g}\frac{dV}{dt} - W\frac{dh}{dt} + \frac{dQ}{dt} - \frac{dW_m}{dt} = 0$$

In this equation, $(W/g)VdV/dt$ represents the effect of increase of air speed, dh/dt that of increase in altitude, and dW_m/dt the power expended in overcoming the drag at an air speed V; dQ/dt is the result, in useful power, of the fuel input. The power spent in overcoming drag, dW_m/dt may be written as DV. The incremental change in energy of the system is now

$$-\frac{WV}{g}\frac{dV}{dt} - W\frac{dh}{dt} + \eta H\frac{dW_f}{dt} - DV = 0 \quad (1)$$

This equation is the basis for all subsequent derivations.

* Project Engineer, Research Department.

Climb

Rearranging Eq. (1) gives

$$\frac{dh}{dt} = \eta \frac{H}{W}\frac{dW_f}{dt} - \frac{DV}{W} - \frac{V}{g}\frac{dV}{dt} \qquad (2)$$

If the climb is made at constant speed, the last term of Eq. (2) disappears.

For the airplane with boundary-layer control a substitution must be made for the term $\eta(H/W)\,(dW_f/dt)$, since fuel is being expended both for thrust and for *BLC*, at different efficiencies. To do this, we write an expression for the useful power obtained from the expenditure of fuel for each purpose. That for thrust, in derivative form is $\eta_P H(dW_{fp}/dt)$. For the *BLC* system, it is convenient to think of *BLC* as contributing a thrust increment rather than a drag decrement, to retain the concept of useful work being done by the fuel. If the air horsepower of the system were reflected directly as "thrust"—(i.e., drag-decrement)—horsepower, it could be written as $\eta_{BLC}H(dW_{fBLC}/dt)$. It is not, so an additional factor K_D (not a constant) is introduced to denote that fact, and the useful work of the *BLC* system per second is now $K_D\eta_{BLC}$-$H(dW_{fBLC}/dt)$. The total useful work per second is, then, $\eta_P H(dW_{fp}/dt) + K_D\eta_{BLC}H(dW_{fBLC}/dt)$, and Eq. (2) becomes

$$\frac{dh}{dt} = \eta_P \frac{H}{W}\frac{dW_{fp}}{dt} + K_D\eta_{BLC}\frac{H}{W}\frac{dW_{fBLC}}{dt} - \frac{DV}{W} - \frac{V}{g}\frac{dV}{dt}$$

If the ratio of efficiencies ζ_1 and the ratio of fuel consumptions ζ_2 are introduced

$$\frac{dh}{dt} = \eta_P \frac{H}{W}\frac{dW_{fp}}{dt}\left(1 + K_D\zeta_1\zeta_2\right) - \frac{D_0V}{W} - \frac{V}{g}\frac{dV}{dt}$$

Noting that $\eta_P H(dW_{fp}/dt) = TV$ we have

$$\frac{dh}{dt} = \frac{TV}{W}(1 + K_D\zeta_1\zeta_2) - \frac{D_0V}{W} - \frac{V}{g}\frac{dV}{dt}$$

or

$$= \frac{V}{W}(T - D_0) + \frac{K_D\zeta_1\zeta_2 TV}{W} - \frac{V}{g}\frac{dV}{dt} \qquad (3)$$

The first and last terms constitute the climb expression for a conventional airplane.

K_D is, so far, an unevaluated coefficient the nature of which depends on the aerodynamics of the individual *BLC* system. To determine its behavior, we write the relationship which identifies K_D and which expresses the effectiveness of fuel expended in producing a decrement in drag-power required.

$$K_D\eta_{BLC}H(dW_{fBLC}/dt) = \Delta DV$$

Now $\Delta DV = \Delta C_D(\rho/2)SV^3$ and, from representative flight results,

$$\Delta C_D = -AC_Q\ (A \cong \text{const.})$$
$$= -AQ/SV$$

up to the point where $\Delta C_D = -C_{D_0}$ and possibly somewhat beyond. Also, from the same results, $Q = Q_{V=0} - BV$ (B const.). So

$$\Delta C_D = A(Q_0 - BV)/SV$$
$$\Delta DV = [A(Q_0 - BV)/SV](\rho/2)SV^3$$

Finally

$$K_D\eta_{BLC}H(dW_{fBLC}/dt) = A(Q_0 - BV)(\rho/2)V^2$$
$$K_D = FV^2 - GV^3 \qquad (4)$$

Note that at a given altitude F and G are dimensional constants.

Take-Off

The length of the take-off run cannot be determined by energy methods since part of the *BLC* power is used in producing lift, and in a horizontal ground run the developed lift itself produces no increment of aerodynamic power. It does, however, affect the rolling resistance, so a means of assessing the total effect of *BLC* both lift- and dragwise is necessary.

In Eq. (1), the terms retained are arranged as follows:

$$V(W/g)\,(dV/dt) = \eta H(dW_f/dt) - DV$$

Here the left-hand side represents the change in kinetic energy per unit time (has the dimensions of power), and the right-hand side is to be replaced as before, with the exception that the drag term must now account for rolling resistance, as well as for aerodynamic drag.

The lift of the wing is considered to be equal to the basic lift L_0 in take-off attitude plus the increment ΔL due to *BLC*. Then

$$\text{rolling resistance} = \mu(W - L_0 - \Delta L)$$

ΔL is handled in the same way as was ΔD in the previous section, by introducing a coefficient K_L. The equation for kinetic energy change of the aircraft during the take-off run is now

$$\frac{WV}{g}\frac{dV}{dt} = \eta_P H\frac{dW_{fp}}{dt} + K_D\eta_{BLC}H\frac{dW_{fBLC}}{dt} - D_0V - V\mu\left(W - L_0 - \eta_{BLC}HK_L\frac{dW_{fBLC}}{dt}\right)$$

Since the expression for the effect of *BLC* in the resistance term is written so as to show a contribution to a force (lift) rather than to a power (as in drag power), K_L is dimensional, whereas K_D was not. Its behavior may be investigated similarly to that of K_D.

Rearranging the above equation, substituting as before the ratios of ζ_1 and ζ_2, and solving for the acceleration dV/dt gives

$$dV/dt = (g/W)(T - D_0) - \mu(W - L_0) + (g/W)\,T\zeta_1\zeta_2\,(K_D + \mu K_L V) \qquad (5)$$

wherein the last term represents the effect of *BLC*.

Range

The aircraft now travels in unaccelerated straight and level flight (approximately), and inspection of

Eq. (1) produces the following:

$$\eta H(dW_f/dt) - DV = 0$$

Rewriting the above as

$$Vdt = \eta_P(H/D)\ (dW_{fp}) + K_D\eta_{BLC}(H/D)\ (dW_{fBLC})$$

and making the same substitutions as previously, plus that of $Vdt = dR$, yields

$$\begin{aligned} dR &= \eta_P(H/D)\ (dW_{fp}) + K_D\eta_{BLC}(H/D)\ (dW_{fBLC}) \\ &= \eta_P(H/D)\ (dW_{fp})\ (1 + K_D\zeta_1\zeta_2)\ (L/D_0) \end{aligned}$$

or

$$R = \eta_P H(L/D_0)\ (1 + K_D\zeta_1\zeta_2)\ (dW_{f_p}/dt)$$

The fuel increment dW_f consists of two parts

$$dW_f = dW_{f_p} + dW_{fBLC}$$

or

$$= dW_{f_p} = -[dW/(1 + \zeta_2)]$$

Therefore

$$R = -\eta_P H\left(\frac{L}{D_0}\right)\frac{(1 + K_D\zeta_1\zeta_2)}{1 + \zeta_2}\int_{W_1}^{W_0}\frac{dW}{W}$$

$$-\eta_P H\left(\frac{L}{D_0}\right)\frac{(1 + K_D\zeta_1\zeta_2)}{1 + \zeta_2}\ln\frac{W_0}{W_1} \qquad (6)$$

This equation is plotted in Fig. 1 for various values of ζ_1, ζ_2, and K_D.

Application to Integrated Systems

For an aircraft whose *BLC* system extracts power from the propulsive engine, thereby decreasing its thrust, the approach set forth above is modified as follows:

An "engine efficiency" η_e, representing the efficiency of conversion of fuel energy to shaft power, is introduced. The shaft power devoted to propulsion is now $\eta_e H(1 - x)\ (dW_f/dt)$, and that devoted to *BLC* is $\eta_e Hx(dW_f/dt)$.

The useful propulsion power, obtainable from the propeller, is

$$\eta_{prop}\eta_e H(1 - x)\ (dW_f/dt)$$

and that due to *BLC* is

$$K_D\eta_{BLC}\eta_e Hx(dW_f/dt)$$

The rate of climb equation, for instance, then becomes

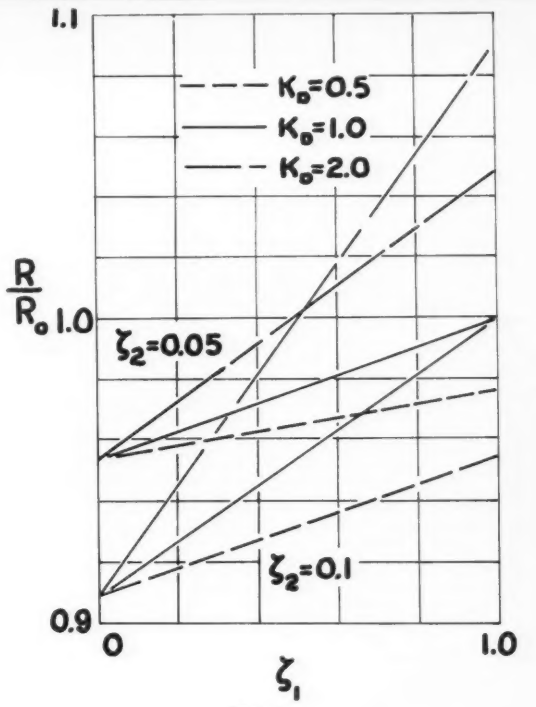

Fig. 1.

$$\frac{dh}{dt} = \frac{1}{W}\eta_{prop}\eta_e H(1 - x)\frac{dW_f}{dt} +$$

$$\eta_{BLC}\eta_e K_D H\frac{dW_f}{dt} - \frac{D_0 V}{W} - \frac{V}{g}\frac{dV}{dt}$$

Noting that the useful propulsive power

$$\eta_{prop}\eta_e H(1 - x)\ (dW_f/dt) = T_0(1 - x)V$$

and introducing ζ_1 as usual, we have

$$\frac{dh}{dt} = \eta_{prop}\eta_e\frac{H}{W}\frac{dW_f}{dt}(1 - x) + \zeta_1 K_D x - \frac{DV}{W} - \frac{V}{g}\frac{dV}{dt}$$

$$= \frac{V}{W}(T_0 - D) + \frac{V}{W}T_0 x(\zeta_1 K_D - 1) - \frac{V}{g}\frac{dV}{dt} \qquad (7)$$

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IAS News

(*Continued from page 23*)

by the J. B. Rea Company, Inc., of Santa Monica, Calif.

Lee H. Smith (M) has been promoted to Director of Military Relations and Customer Service by Northrop Aircraft, Inc.

Romus Soucek (M), formerly Sales Manager of the Aviation Gas Turbine Division, Westinghouse Electric Corporation, has been appointed Manager of Defense Products for the West Coast. His office is in Los Angeles.

J. Carlton Ward, Jr. (M), President of Vitro Corporation of America, has been elected to the Board of Directors of Thieblot Aircraft Company, Inc., Bethesda, Md.

Elmer P. Wheaton (AF) has been promoted to Chief Missiles Engineer of Douglas Aircraft Company, Inc., and placed in charge of the newly formed Missiles Engineering Department at Santa Monica.

CORPORATE MEMBER NEWS

• **Aerolab Development Company,** of Pasadena, Calif., has been acquired by the United States Hoffman Machinery Corporation and will be operated as a subsidiary.

• **Air Associates, Inc.,** has designed a new three-phase, 400-cycle a.c. brake motor to drive the elevon pitch trim system on the Douglas F4D Skyray.

• **Allison Division, General Motors Corporation . . .** The Model 501 turboprop engine, rated at 3,750 h.p., will power American Airlines' fleet of Lockheed Electras. This is the commercial version of the Allison T56.

• **Aluminum Company of America . . .** A number of different color finishes are now available in anodized aluminum sheet, extruded shapes, rod, bar, and tube. The color is "sealed into" the hard oxide coating, becoming an integral part of the metal.

• **American Airlines, Inc. . . .** An interline agreement with Seaboard and Western Airlines will facilitate transatlantic air freight shipments on one airway bill.

• **Arma Division, American Bosch Arma Corporation . . .** Arma's new subminiature gyro compass, which weighs 22 lbs. including the control unit, has been tested successfully in a helicopter by the Army Corps of Engineers' Research and Development Laboratories at Fort Belvoir, Va. An Army press release said it maintained "traditional battleship accuracy in flight." The gyro compass can be carried in one hand and is rugged enough to use in an Army tank. It can be operated by nontechnical personnel. It is not affected by magnetic storms, changes in magnetic structure of the vehicle frame, or d.c. fields from motor or radar operation. In addition, it eliminates deviation corrections and performs accurately at latitudes as high as 80°. This high-accuracy gyro compass, no bigger than a $10^1/_2$-in. cube, is now in production and available for commercial, as well as military, use.

• **Bendix Aviation Corporation . . .** Representatives of 20 foreign and domestic air lines attended a Fuel Systems Forum sponsored recently by the Bendix Products Division in South Bend, Ind. One of the highlights was a work book prepared in advance by Bendix, based on questions relating to problems, special techniques, tools, and fixtures, which the participants had sent in before the meeting. . . . Bendix Radio Division is marketing a new synchronizer-power supply unit for Bendix X-band and C-band air-borne weather radar systems. Model SYN-1B weighs 21 lbs., or 27 lbs. less than its larger predecessor. Numerous improvements have given the air-borne weather radar systems improved reliability and performance, better accessibility to components, reduced weight, and reduced power consumption. The use of higher quality components and new circuits made the improvements possible. . . . The Bendix plant at Eatontown, N.J., is turning out generators that can operate at internal temperatures of 400°F. These are intended for high-speed jet planes in which the cooling air available to the generators is hotter than boiling water —sometimes as hot as 248°F. The unprecedented heat tolerance is obtained by using materials such as glass laminates, silicones, and mica, and by brazing electrical connections with a silver solder. . . . A $2,000,000 expansion program is nearing completion at the Bendix Scintilla Division in Sidney, N.Y. A new engineering building has been erected, giving the plant a total floor area of 550,000 sq.ft. . . . The Pioneer-Central Division, which recently completed an addition to the main plant in Davenport, Iowa, has purchased a 23,000-sq.ft. building near the plant.

• **Boeing Airplane Company . . .** The 707 jet transport was flown by 18 pilots representing five different air lines during a series of demonstration flights in September. The air-line officials handled the controls on 27 flights totaling 10 hrs. 18 min. Five of them, representing the Society of Automotive Engineers, ruled that the 707's cockpit conformed to new standards set by the SAE. . . . The Boeing 707 will have a direct operating cost well below that of present four-engine transports at ranges beyond 500 miles, the company claims. It will have a decided economic advantage in overseas flight, as its greater range and speed will make possible nonstop service with single, rather than double, crews. . . . The first of several B-50 long-range bombers modified for weather reconnaissance has joined the USAF Air Weather Service for hurricane duty in Bermuda. The B-29's now used for tracking tropical hurricanes will be retired.

• **Convair, A Division of General Dynamics Corporation . . .** The first TF-102A, called a "combat proficiency trainer" for the delta-wing jet interceptor, is undergoing flight tests at Edwards AFB. The two-place, side-by-side trainer is in production at Convair-San Diego. It has a wider nose section and cockpit than the supersonic F-102A, requiring slight redesign of the air ducts, canopy, and windshield. Some internal equipment also was relocated. . . . At its Fort Worth plant, Convair is modifying 36 C-54 transports for all-weather search and rescue operations. The conversion calls for installation of larger fuel tanks, more electronic devices, blister-type windows, and rescue equipment to be used at the scene. The Air Force will call the modified planes SC-54's.

• **Douglas Aircraft Company, Inc. . . .** A Missiles Engineering Department has been formed at Santa Monica, and the staff will move into a separate building next spring. Currently engaged in eight major missiles projects, the company decided to separate missiles engineering from the aircraft engineering functions.

• **Eastern Air Lines, Inc. . . .** The Board of Directors has authorized a $350,000,000 expansion program during the next 5 years, based on long-term financing for equipment purchases. Captain E. V. Rickenbacker, Board Chairman, said 40 Douglas DC-7B's and ten Lockheed Super-G Constellations will be added to the fleet by 1958 at a cost of $125,000,000. Most of the present four-engine planes will be converted to coach service, which Eastern expects to comprise about half its operations. Twin-engine planes will be assigned to local routes. Forty Lockheed Electra turboprop transports, to cost $100,000,000, are scheduled for delivery during the year beginning August, 1958. Eastern has earmarked $125,000,000 for 20 jet air liners to go into service in 1960, but has not chosen the model.

• **Edo Corporation** celebrated its thirtieth anniversary on September 29. Earl D. Osborn, AMIAS, whose initials formed the name of the new company, is still active as Chairman of the Board. The first Edo product was a 110-hp., all-metal flying boat, but the company soon switched to the design and construction of all-metal floats. During World War II Edo built thousands of floats for nine different Navy and Air Force planes. In addition to floats, Edo now manufactures an air-dropped lifeboat for rescue operations, loran and radar units for marine navigation, and sonar scanning systems for sounding ocean depths or locating schools of fish.

• **Ethyl Corporation . . .** B. Bynum Turner has been promoted to the new position of Executive Vice-President.

• **Fairchild Engine and Airplane Corporation . . .** Fairchild Aircraft Division has leased the plant facilities of Jonco Aircraft Corporation near Shawnee, Okla., for future expansion. The main building has 90,000 sq.ft. of manufacturing space. . . . Stratos Division is constructing a building of 20,000 sq.ft. and renovating an existing building at its Western Branch in Man-

MATS Beats Flight Program Schedule with Allison Turbo-Prop Engines and Aeroproducts Propellers

To MATS' 1700th Test Squadron – Congratulations for a good job well done.

This month, the final hour will be flown on a program which has as its target 3000 flight hours by January 30, 1956 on two Convair YC-131C aircraft powered with Allison Turbo-Prop engines and Aeroproducts Propellers. The program will be completed more than 30 days ahead of schedule – thanks to the skill and enthusiasm of the pilots and crews who were given the job to do.

The aircraft were delivered to MATS at Kelly AFB, San Antonio, Texas, in January, 1955. The 1700th Test Squadron had just been activated and was composed of men who not only were outstanding in their abilities but who demonstrated a genuine enthusiasm for Turbo-Prop transports in military aviation.

Colonel Claude Smith, Commander 1700th Air Transport Group, and his staff immediately initiated a familiarization program for all personnel and the entire squadron set out to obtain maximum time on the two aircraft. The object was to prove the place of turbo-prop-powered transport in military aviation.

Hours on the aircraft mounted rapidly. Sometimes the planes shuttled between Kelly AFB and Travis AFB, or to Andrews, or to the Allison plants in Indianapolis. And many days went by with pilots making operational flights over Texas. Three and four flights a day with five hours per flight became routine. And in one 24-hour period, each aircraft was kept in the air for 23 hours and 10 minutes.

It was long, hard work for pilots in the air and crews on the ground. But they kept at it – determined not only to beat their schedule but to demonstrate convincingly to others the firm, determined faith they have in the future of turbo-prop power.

Under Lt. Col. Samuel C. Burgess, Commander, the work of the 1700th Test Squadron will continue with other aircraft powered with turbo-prop engines. But the pioneering phase of the program is concluding. The rest of the program has been aided immeasurably by the experience gained with the first aircraft assigned to the project.

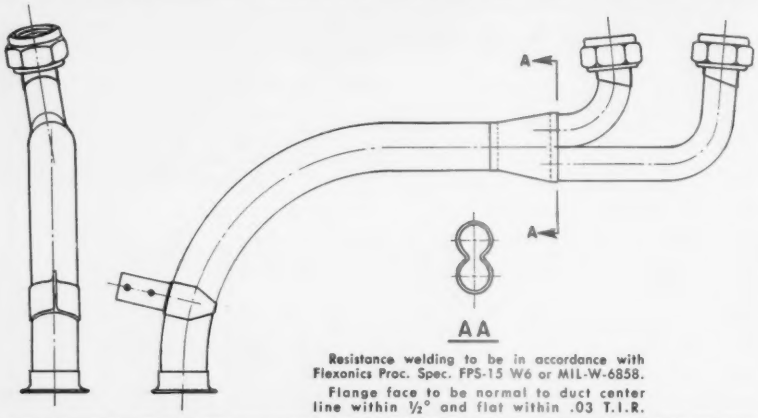
We at Allison salute the good work of the men of the 1700th Test Squadron. We are proud to have been part of the project. You have proved that turbo-prop engines and propellers are "ready to go" and we are gratified that the convincing demonstration was made with Allison Turbo-Prop engines and Aeroproducts Propellers.

ALLISON
TURBO-PROP ENGINES

Allison Division of General Motors
Indianapolis, Indiana

FLEXON DUCTING *Design Briefs*

Complex Anti-Icing Duct Problem Solved with Unique Assembly Engineered by Flexonics



Resistance welding to be in accordance with Flexonics Proc. Spec. FPS-15 W6 or MIL-W-6858.
Flange face to be normal to duct center line within ½° and flat within .03 T.I.R.

Check **FLEXONICS** *for any of these components*

FLEXON DUCTING, standard or high strength corrosion resistant steel, is available in varying wall thickness in light gauges and in a complete range of sizes, with or without insulation. Elbow forming and rib reinforced types can also be supplied.

FLEXON METAL HOSE, corrosion resistant steel, is manufactured in the broadest varieties of sizes and types for all aircraft applications.

FLEXON BELLOWS are made in an almost unlimited range of sizes and types to meet the most advanced requirements.

Intricate forming problems combined with the high dimensional accuracy requirements in production created a tough development problem in the anti-icing duct assembly sketched above. The transition-tube shown in cross-section A-A was inert arc butt formed from a single piece of welded SS 321 tubing (not two half shells welded together). The assembly is proof tested at 365 psig for five minutes. No evidence of leakage, cracking or deformation is permitted. Duct operates at 850° F.

Here's another example of the kind of weight-saving and sound engineering design resulting from years of practical experience and the most advanced manufacturing techniques. You can put this skill to work for you by sending an outline of your ducting requirements. Flexonics engineers welcome the opportunity to work with you towards the resolution of your ducting problems.

RFA-27

Flexonics *Corporation* AIRCRAFT DIVISION

1309 S. THIRD AVENUE • MAYWOOD, ILLINOIS

FORMERLY CHICAGO METAL HOSE CORPORATION

Flexon identifies products of Flexonics Corporation that have served industry for over 53 years.

Manufacturers of flexible metal hose and conduit, expansion joints, metallic bellows and assemblies of these components.
In Canada: Flexonics Corporation of Canada, Ltd., Brampton, Ontario

hattan Beach, Calif. About 200 persons will be employed in the newly acquired plant. Stratos Division recently announced an engineering and product interchange agreement with Sir George Godfrey and Partners, Ltd., of Hanworth, England. . . . American Helicopter Division has moved from Manhattan Beach to 118 East 16th Street, Costa Mesa, Calif.

• **Flight Refueling, Inc.** . . . The Navy has announced that all its new fighters now in production are being fitted with gear for refueling in flight. A number of carrier squadrons are already equipped. The probe and drogue system manufactured by Flight Refueling, Inc., has been adopted as standard. The Navy jet planes now being equipped to receive fuel in flight are the Grumman F9F Cougar, Grumman F11F Tiger, McDonnell F2H Banshee, Chance Vought F7U Cutlass, and North American FJ Fury. North American AJ bombers, the heaviest carrier-based aircraft to date, have been converted to serve as aerial tankers.

• **The Garrett Corporation** . . . AiResearch Aviation Service Division, which operates a base for business aircraft and private planes at Los Angeles International Airport, has leased 25 acres of adjacent airport property and will construct a $600,000 hangar and administration building there. The structure will contain four hangars under one 300 by 300-ft. roof and a lounge for pilots and passengers.

• **G. M. Giannini & Co., Inc.** . . . With sales setting a record, the Airborne Instrument Division has been divided into three parts called the Gyro, Systems, and Transducer Divisions. . . . An Applied Physics Activity has been formed to develop new products.

• **The Goodyear Tire & Rubber Company, Inc.** . . . The company is in the midst of a 2-year program of plant expansion and improvement involving a capital outlay of $100,000,000. New factories or additions will be constructed in several American cities and in Scotland, Colombia, and Venezuela. At Akron, Ohio, the company is investing $3,300,000 in a new research and development laboratory for Goodyear Aircraft Corporation. About $240,000 will be spent on a new aircraft and electronics laboratory at Litchfield Park, Ariz. . . . The annual Wheel and Brake Clinic of Goodyear's Aviation Products Division attracted 70 engineers and maintenance men representing air lines, aircraft manufacturers, and the military services. The discussions, held in Akron, covered airplane tires and tubes, wheels and brakes, rubberized fabric, fuel cells, and electrothermal equipment for protection against icing.

• **Grumman Aircraft Engineering Corporation** . . . Grumman's S2F-2 "sub killer," now in production, is the first airplane designed specifically to detect, identify, track, and destroy enemy submarines. The twin-engine plane, carrying a crew of four, utilizes radar, sonobuoys, and magnetic air-borne detector to pinpoint the sub, and then chooses either torpedoes, depth charges, or rockets to make the kill. It operates from carriers and has navigational equipment for severe weather conditions. . . . Grumman has contributed $1,000 to a cooperative research program

Flame tube

. . . heart of the modern turbo-jet

JET PROPULSION remained impractical until recent years. Until development of alloys that could meet the need for stability at elevated temperatures.

Today's super-sonic speeds are possible thanks to flame tubes, turbine blades and other vital parts made from high-nickel alloys.

Ever since the days of its first piston engine, the aircraft industry has used nickel alloys . . . widely. The piston engine still powers 99 per cent of all commercial planes. It will no doubt be used for years to come . . . with continued help from nickel alloys. Especially where assailed by heat or cold, corrosion or wear, steady stresses or shock loads.

Perhaps high heat . . . sub-zero cold . . . corrosion or some complex problem is troubling you or your staff. Send us the details. Let us study them. We'll give you our suggestions based on wide practical experience.

Write for . . . "List A" of available publications. A simple form makes it easy for you to outline your problem.

INCO TRADE MARK

Typical Alloys Used in Jet Engines

Part	Material	Average Nickel (%)
Combustion Liners (Flame tubes)	Inconel®	78
	Incoloy®	33
	Nimonic 75	75
	Type 310 Stainless	20
Combustion Chambers	Type 321 Stainless	9
Tail Cones	Types 321, 347, 310 Stainless	8 to 20
Afterburner	Inconel W®	74
	Inconel X®	73
	N-155	20
Buckets (Blades)	S-816	20
	Stellite 31	10
	Waspoloy	59
Wheels (Discs) Composite	4340 (hub) 16-25-6 (rim)	2 to 25
	A 286	25
	Discaloy	26
Fuel Line Tubing	Inconel	78
	Type 321 Stainless	9
	Monel®	67

THE INTERNATIONAL NICKEL COMPANY, INC. 67 Wall Street New York 5, N.Y.

Lockheed's newest Super Connie, the 1649A, has completed 1,000 hours of wind-tunnel testing, the company announced. On scale model of the long-range transport in Lockheed wind tunnel, Paul W. Theriault (*left*), MIAS, points out extra wing length to John B. Wassall, MIAS, Assistant Chief Engineer. The 1649A will have longer, thinner wings than the present Constellation. Its range will be increased to 6,000 miles and cruising speed to 350 m.p.h.

at Rensselaer Polytechnic Institute aimed at solving problems involved in the friction and lubrication of solids.

• **Harvey Aluminum Division, Harvey Machine Co., Inc.** . . . Construction will begin early in 1956 on a reduction plant at The Dalles, Ore., the company announced after signing a contract with the General Services Administration for a $65,000,000 primary aluminum facility. The plant will have an annual capacity of 108,000,000 lbs., making Harvey the nation's fifth largest producer of primary aluminum. . . . Harvey has embarked on a campaign to make the latest technical information available to industrial designers and engineers, so that they may take advantage of the capabilities of the new heavy hydraulic forging presses in planning new products.

• **Johns-Manville Sales Corporation** . . . Don L. Hinmon, General Manager of the new Industrial Insulations Division of Johns-Manville Corporation, has also been elected a Vice-President of Johns-Manville Sales Corporation. J. B. Jobe and Edward D. Flavin also have been elected Vice-Presidents.

• **Lockheed Aircraft Corporation** . . . A huge jig used in building the 150-ft. wing of the long-range 1649A Super Constellation is believed to be one of the largest precision tools ever made for aircraft work. Workmen at different stations talk to each other by telephone. Accuracy is insured by the use of optical equipment. Built-in aluminum "yardsticks" correct for differences in expansion or contraction caused by temperature changes. The jig can be moved as assembly lines expand. Previously, Lockheed has built wings in right and left sections, and mating has been a six-phase operation, with the inner wings, outer wing panels, and tips joined successively. . . . The F-104, a relatively lightweight jet fighter in which complexity has been reduced to gain more speed and performance, is in production at Burbank. A prototype is flying at Edwards AFB.

• **Marquardt Aircraft Company** . . . A ram-air emergency power package installed in the Chance Vought XF8U-1 day fighter will bring the airplane home if other power sources fail. The Marquardt unit supplies sufficient electrical and hydraulic power to maintain flight control and communication at all speeds, including safe landing speed. If the pilot is faced with an emergency such as a flameout of the jet engine or failure of the main alternator, he triggers the machine into the air stream. The ram-air turbine starts rotating immediately to drive the hydraulic pump and electric generator. Within a few seconds, the pilot has power for an aerial restart and for his radio, instruments, controls, and landing gear. . . . Marquardt's Research Division has moved to larger quarters adjacent to the production and engineering plants in Van Nuys, Calif.

• **McDonnell Aircraft Corporation** . . . Wing skins for the F-101 Voodoo are being formed on a 10,000-ton hydraulic press. A complete skin of 94 sq.ft. is stretch-pressed in one operation. The thin, swept-back wings of the twin-jet supersonic fighter consist of four heavy, tapered, preformed skin sections. It requires from 3 to 8 days to set up the dies for each section, but a new skin can be turned out every 15 min. As the Voodoo skins were previously subcontracted, shipping costs have been eliminated and damage reduced.

• **Minneapolis-Honeywell Regulator Company** . . . The Aeronautical Division has developed a transistorized exhaust-gas-temperature indicator system suitable for turbojet or turboprop installations. Its indicating range is 1,000°. Elimination of vacuum tubes, reduction in the number of moving parts, inherent ruggedness of the diode and transistor components, and the manner in which electronic circuitry is designed around them make the new system more reliable and more accurate than previous types, the company claims. The apparatus weighs only 0.8 lbs. and occupies 17 cu.in., in contrast to comparable vacuum-tube systems weighing 3.5 lbs. with a volume of 130 cu.in. . . . The Aeronautical Division has developed a transistorized fuel-measuring system that also warns the pilot if the plane's center of gravity is threatened by improper fuel distribution. An indicator shows him at a glance which fuel tank he should select to restore balance for safe flight. Designed for the Grumman F11F-1 jet fighter, the system continually and automatically shifts from fuel-quantity measurement to fuel-balance sensing.

• **North American Aviation, Inc.** . . . The last F-86D Sabre Jet interceptor has been delivered to the Air Force, bringing to an end 4½ years of production. Loaded with automatic electronic equipment, the

Minneapolis-Honeywell Regulator Company is cutting costs of experimental breadboard assemblies with an "Erector Set" designed by tool test technicians of the Aeronautical Division. The kit contains sheets of perforated fiberboard in various sizes and an assortment of standardized brackets and mounts. The parts can be used over and over. Photos and diagrams of each temporary fixture are preserved so that it could be duplicated again.

F-86D was the first of the one-man interceptors. It also was the first to use air-to-air rockets. . . . North American has announced it will award up to ten college scholarships annually to children of employees. Each winner will receive tuition fees up to $650 and an expense allowance of $400 a year. In addition, the company will give $500 to the college he attends. Candidates will be selected by competitive examination and may attend any school they choose. The scholarships are limited to students taking engineering, related sciences, or business administration. They do not entail any obligation to work for North American after graduation.

• **Northrop Aircraft, Inc.** . . . Edward W. Carter has been elected to the Board of Directors. He is President of Broadway-Hale Stores, Inc., a California department store chain, and active in civic affairs.

• **Nuclear Development Corporation of America** plans to build a reactor "critical" facility at its Nuclear Experimental Station in Dutchess County, N.Y. It will be used in the reactor engineering program carried out for governmental and industrial clients by N.D.A. The company also plans to construct a "hot" laboratory to study and examine radioactive fuel elements and reactor structural components irradiated elsewhere in N.D.A.'s reactor programs. About $400,000 will be spent on the initial installations.

• **Pan American World Airways, Inc.** . . . With 45 jet transports on order—20 Boeing 707's and 25 Douglas DC-8's—Pan American anticipates greatly increased traffic in 1959, when Paris will be only 6½ hrs. from New York and Tokyo will be 8½ hrs. from Seattle. Flying time from San Francisco to Honolulu will be cut to 4½ hrs. The Boeing and Douglas air liners, both powered by Pratt & Whitney axial-flow jet engines, will carry more than 100 passengers at 575 m.p.h. P.A.A. said its fleet of jet clippers will cost $269,000,000. In addition, Douglas is building 33 DC-7's for delivery to Pan American next year. . . . Pan American has inaugurated Latin-American service via San Francisco. The route connects with other South American flights at Panama and Caracas. . . . Everett M. Goulard has been promoted to Vice-President in charge of Industrial Relations.

• **J. B. Rea Company, Inc.,** plans to construct a 40,000 sq.ft. building adjacent to its plant in Santa Monica, Calif. . . . The company is marketing a new analog-to-digital converter called the "Rea-Converter." . . . Daniel T. Gunderson has been elected a Vice-President.

• **Reaction Motors, Inc.** . . . Located on a 50-acre site near Denville, N.J., a new $4,000,000 rocket engine plant constructed in cooperation with the Navy was dedicated recently. . . . Reaction Motors received the 1955 Air Power Achievement Award of the New Jersey Wing of the Air Force Association.

• **E. V. Roberts and Associates,** Los Angeles, has been appointed to cover California, Arizona, and New Mexico as representative of Unitek Corporation, manufacturer of stored-energy spot welders.

• **Stroukoff Aircraft Corporation** was recently honored by the New Jersey Wing of the Air Force Association with the Air Power Achievement Award for 1955.

MALLORY·SHARON reports on
TITANIUM
This jet engine jacket of Mallory-Sharon titanium was design-strengthened by Rigidized Metals Corporation, and formed to shape by Convair.

This jet's engine wears a wrinkled jacket

HERE'S Convair's F-102A, new entry in the supersonic field. Original models used a titanium shroud—or jacket—for the jet engine to save 40% in weight over a comparable steel part. In the latest models, Convair has introduced a new wrinkle to save even more weight.

Notice the dimpled appearance of the engine jacket? By dimpling or "design-strengthening" the entire surface, thinner gage titanium can provide the same structural strength as a thicker smooth piece.

New forming techniques like this have been made possible in recent months because of major improvements in titanium's mechanical properties, and much stricter quality levels. At the forefront of such developments you'll find Mallory-Sharon, leading producer of titanium and titanium alloys.

Use our experience for *your* applications of this strong, lightweight, corrosion-resistant metal. Write Mallory-Sharon Titanium Corporation, Niles, Ohio.

MALLORY Ti SHARON

• **United Air Lines, Inc.** . . . . Instruction in the use of air-borne C-band weather mapping radar has begun for United's 1,785 pilots. The company has announced it is spending $4,000,000 on the radar units and installation. . . . United Air Lines has signed a cargo interline agreement with Seaboard and Western Airlines to expedite transatlantic shipments.

• **Vickers Incorporated** is manufacturing a new line of lightweight, hydraulically pressurized reservoirs for aircraft oil-hydraulic systems that hold constant pressure and permit higher temperatures. The fluid is maintained at pump inlet pressure by a differential piston device operated by pump discharge oil at system pressure. Constant inlet pressure for the hydraulic pump is provided under all flight conditions, independent of attitude, altitude, engine speed, and temperature. The new reservoir design also results in an airless system, permitting today's fluids to be used at temperatures considerably higher than has been possible in the past. Eliminating air from the system greatly increases the temperature at which hydraulic oils and fluids may be used without breakdown and sludging due to oxidation. One version of the new reservoir is designed especially for use with the newer jet engines.

• **Western Gear Works** has changed its name to Western Gear Corporation.

• **Westinghouse Electric Corporation** . . . To acquaint the air lines with a.c. electric systems, which will be installed in jet and turboprop air liners, the Aircraft Equipment Department held a 2-day conference attended by representatives of five large air lines. Air-line experience to date has been confined mostly to d.c. equipment. . . . An electronic computer-simulator has been installed by the Air Arm Division in its new $1,000,000 addition at Friendship International Airport, Baltimore.

IAS SECTIONS

Meet Your Section Chairman

George R. Mellinger

Los Angeles Section

George R. Mellinger, a native of Waseca, Minn., received his Bachelor of Arts degree from Drake University in Des Moines, Iowa, in 1936. This was followed by graduate study at the California Institute of Technology, where he received the degrees of Master of Science in Mechanical Engineering in 1937 and Master of Science in Aeronautical Engineering in 1938. While at Caltech he was elected to Sigma Xi, an honorary scientific fraternity.

His interests were not entirely academic during his school years. He played varisity football at Drake for three years, being chosen team captain in 1935. At Caltech he coached the freshman teams in football and basketball and served as Resident Associate of one of the undergraduate student houses.

After leaving Caltech, George went to San Francisco, where he worked in flight engineering for Pan American Airways until 1940. He then took a position with North American Aviation, Inc., in Los Angeles and has been with that company, in Aerodynamics and Flight Testing, ever since. At present he is Chief of Experimental Flight Test, a position that he has held for the past five years.

George is an Associate Fellow of the Institute and has been active in the affairs of the Los Angeles Section for about ten years. He has served as Section Secretary (1946), Nominating Committee Member (1951), Program Committee Chairman (1954), and Section Vice-Chairman (1955).

The Los Angeles Section, with about 2,200 members, is the largest local unit of the IAS, and one of the oldest.

George and his wife and teen-aged son and daughter live in the Brentwood section of Los Angeles, where they are looking forward to moving into a new home, now under construction, sometime next spring. He has been active in the affairs of the Youth House in his community and, in spite of his varied program of interests, finds time for an occasional game of tennis.

The Viscount

Cleveland-Akron Section

Jack T. Dyment, Director of Engineering, Trans-Canada Air Lines, addressed the first fall meeting at the Manger Hotel, Cleveland, on September 20. His paper was entitled, "Operational Experiences with Turboprop-Powered Transport Aircraft."

During the day, Trans-Canada Air Lines had offered complimentary flights on the Vickers Viscount to all those who planned to attend the meeting, thus affording them an opportunity to observe the turboprop air liner in operation.

Dyment presented an interesting review of the operating experience that Trans-Canada Air Lines has accumulated with the Viscount since putting the plane in operation in March, 1955. His talk included discussions of the reasons why T.C.A. selected the Viscount, past history of the Viscount in Europe, construction details of the airplane, power plant design, performance and operation, and operating characteristics of the airplane as observed by T.C.A. He also expressed his viewpoint on the future of turboprop-powered transports in continental North America, and indicated what power plants he thought would be available between now and 1960 for such aircraft.

Of particular interest in his discussion was the fact that currently the delay time of the Viscount due to components of the aircraft or engine malfunctioning is less than that experienced with the Super Constellations that Trans-Canada has in operation. About 50 per cent of the delays are caused by malfunction of electrical or instrument systems. Only one delay has been experienced as a result of engine malfunction. He felt that in view of the fine operational record of the airplane, in combination with its comfort and speed, the Viscount has a bright future in air-line operation in this country.

About 175 persons attended the meeting.

WILLIAM A. FLEMING, *Secretary*

Medical Research

Columbus Section

J. J. Swearingen, Chief of the CAA Medical Research Laboratory of Columbus, Ohio, discussed the activities of the Medical Research Laboratory at the September 20 meeting.

This laboratory was described as the only institution in the world devoted solely to research in the aero-medical aspects of civil aviation, where passengers of all ages—zero to 100—and in various states of health must be considered. One eye must be kept on the more important problems of the present, but the main investigations must deal with the future, where problems of a different order of magnitude exist.

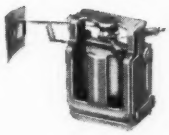
With present commercial airplanes flying at 25,000 ft. and below, decompression is no problem; but with the advent of the jet air liner crusing at 40,000 ft., important design criteria must be set up for both the airplane and the equipment. In the event of decompression at 40,000 ft., a passenger would

Instrument Mechanisms

from the World's foremost builder

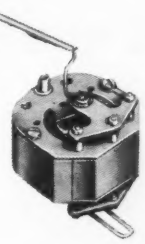
Whether the instrument system requires mechanisms combining miniature size with high torque, or great deflection with high sensitivity, or 'most any other combination of specific instrument characteristics... more than likely there's a WESTON mechanism already available which meets the requirements *exactly*. But for new or unusual needs, Weston engineers are available to assist at the drawing board stage. In either case, Weston's long leadership in instrument design... *since 1888*... offers best assurance of getting mechanisms *specifically designed for*, rather than merely adapted to, the system. WESTON Electrical Instrument Corporation, 614 Frelinghuysen Avenue, Newark 5, New Jersey.

Model 9934—Miniature, self-shielded core magnet mechanism designed for operation of warning flags where space requirements are critical. Capable of 90° total deflection.

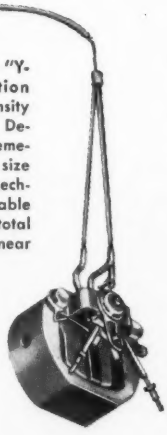


Model 9889—Small self-shielded core magnet mechanism featuring spring-backed jewels for ruggedness and the requirements of vibration and shock; suppressed characteristics if desired; optional location of mounting. Capable of 90° total deflection and can be used for both warning flags and indicator.

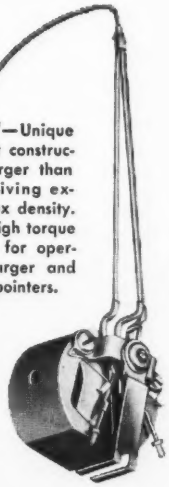
Model 9897—Long scale, 250° self-shielded movement, linear motion for operation of pointers where great deflection is a requirement. Capable of sensitivities in the order of 1½ microamperes per degree deflection.



Model 9891*—Unique "Y-Cor" magnet construction giving very high flux density with very high torque. Designed for operating extremely long pointers. Small size makes it ideal for multi-mechanism instrument use. Capable of 45° (22.5-0-22.5°) total deflection, essentially linear up to 40° (20-0-20°).



Model 9890*—Unique "Y-Cor" magnet construction, slightly larger than Model 9891, giving extremely high flux density. The extremely high torque makes it ideal for operation of the larger and heavier type pointers.



Model 9929—Self-shielded core magnet mechanism of high flux density. Designed for operating pointers with high moments of inertia. Total deflection up to 120 degrees available. Also available in miniature size (Model 9892).

**These Models useful as sensitive, self-shielded galvanometers.*

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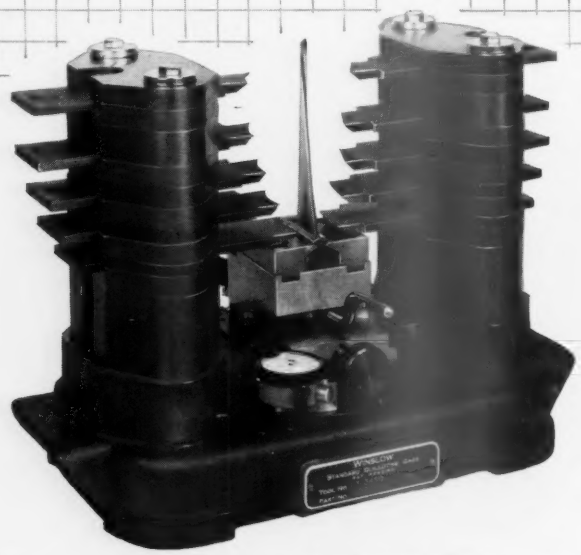

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- quick delivery
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- maintains original accuracy
- lower original cost
- less down-time
- quickly re-worked for parts changes

Already in use by the leaders of the jet engine industry, this new kind of guillotine gage solves the problem of maintaining accuracy. Templates are supported over a much larger area of their surface, making wear negligible. And alignment is guaranteed by heavy stacked towers that are bolted together for ruggedness and complete rigidity. Winslow's new design and assembly from precision-built interchangeable parts give six big advantages. You get quick delivery and lower original cost. You save on maintenance—in case of damage substitution of some parts can be made without even removing the gage from your inspection line.

Gage down-time is cut, requiring fewer gages and avoiding costly production holdups. And finally, you reduce your gage investment with a truly multi-purpose instrument—check all 10 features of a jet engine blade with a single gage; check forging and finished part with only one gage. No more gage obsolescence—Winslow's Re-Work Service quickly up-dates the gage when your part changes. Easy to use and easy to read, the Winslow speeds production, gives "more accuracy for less money."

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become unconscious in 15 sec. and would die in 45 sec. because of lack of oxygen. In the interval of the 15 to 45 sec., the brain begins to deteriorate. The following requirements were set up for an oxygen mask:

(1) An inexperienced passenger must be able to put it on in 3 or 4 sec.

(2) The mask must have no right-side-up.

(3) The mask must have no straps or buckles.

(4) The mask must fit infants as well as grown-ups.

(5) The mask must provide 100 per cent oxygen.

A mask has been designed to fit these requirements. An aneroid mechanism ejects the mask in front of the passenger 0.02 sec. after decompression occurs. Test runs have proved that the mask can be put on in 3 or 4 sec.

The Medical Research Laboratory's work is carried on in other basic fields. In studying the bail-out problem at high speed, wind-tunnel tests have been made with the human body mounted on a six-component balance with wind velocities from 20 to 160 m.p.h.

Another major field of activity is crash investigation to improve the survivability of passengers during the accident by proper body support and after the actual crash by decreasing the danger of death by fire.

JAMES T. OVERBEY, *Secretary*

Hagerstown Section

A dinner dance and installation of officers opened the 1955–1956 season on September 24. Forty-three members and wives attended the affair at the American Legion Home.

The meeting was opened by the retiring Vice-Chairman, R. E. Eisiminger, who expressed appreciation for assistance received during his term. J. Allen Clopper, incoming Chairman, introduced the new officers and committee chairmen, and outlined some of his plans for the coming year.

Los Angeles Section

Donald Coles, Senior Research Fellow, California Institute of Technology, spoke to 40 members and guests of the Los Angeles Section at a specialist meeting on September 6. His subject was "The Nonequilibrium Turbulent Boundary Layer." The talk was illustrated with slides. Coles suggested a representation for the mean velocity distribution in a nonequilibrium turbulent boundary layer. The representation consists of two functions whose relative importance is established by the magnitude of a certain characteristic parameter. Two additional parameters were introduced in satisfying the requirements of continuity. The validity of

such a representation was justified by showing its possible use in connection with the turbulent and laminar equilibrium profiles in accelerating and decelerating flow.

ARTHUR MAGER
Specialist Meetings Committee

San Diego Section

The October 11 meeting was devoted to a talk on "Operational Aspects of Turboprop Transport Aircraft" by Col. Claude W. Smith, USAF, Commanding Officer of the 1,700th Air Transport Group stationed at Kelly Air Force Base, San Antonio, Texas. He discussed performance, maintenance, reliability, and other operational characteristics of turboprop airplanes in general and the Convair C-131C in particular. He made general comparisons between various turboprop types (including the Vickers, Boeing, Lockheed, and Convair airplanes) and the presently used reciprocating transports and contemplated turbojet models. The Convair C-131C turboprop transport which Colonel Smith has been evaluating for the Air Force was on display adjacent to the IAS Building before and after the meeting. Flights in the C-131C were scheduled for a number of IAS members for the following day, but had to be cancelled because of bad weather.

▸ On October 4, the San Diego Section joined the Institute of Radio Engineers, the Acoustical Society of America, and San Diego State College in sponsoring the San Diego Noise Symposium at the college. Eight papers were presented in three sessions, beginning at 3 p.m.

▸ At the annual business meeting and dinner September 27, Hal Luskin, Assistant Chief Aerodynamics Engineer, Santa Monica Division, Douglas Aircraft Company, Inc., presented a paper on "The Supersonic Airplane." He discussed such matters as how fast supersonic airplanes will go, how high they will fly, how much noise they will make, and how reliable they will be.

Retiring Chairman James G. Wenzel was given the Chairman's Key for his excellent service during the past year. The following new officers were installed: Chairman, E. R. Hinz; Vice-Chairman, H. C. Matteson; Treasurer, D. P. Germeraad; Corresponding Secretary, R. A. Fuhrman; Recording Secretary, P. E. Culbertson; and Area Councilor Nominee, H. L. Braasch.

▸ On September 1, Krafft A. Ehricke, Design Specialist, Convair-San Diego, presented the fourth and last of his series of lectures on space flight problems. He discussed the problems of flight to other planets and included the subject of total distance limitations as they are determined by "one generation flight."

R. A. FUHRMAN
Corresponding Secretary

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Seattle Section

The September 28 dinner meeting was held at the Officers Club of Sand Point Naval Air Station. Chairman Joe Barfoot introduced the new officers and the guest speaker, John F. Victory, Executive Secretary of the National Advisory Committee for Aeronautics.

Victory, who joined the NACA 40 years ago as its first employee, outlined the history and organization of the Federal Government's aeronautical research agency, which now has a staff of 7,500 and a budget of $75,000,000.

During the First World War, he said, the aircraft industry was unified by the theme "We want an engine," and the Liberty engine came into existence. By this time, there was need for uniformity in aircraft "lingo," and the late Joseph S. Ames was appointed Chairman of the NACA's Nomenclature Committee.

The NACA assisted in promoting air mail service, but its first great contribution to the aircraft industry was the design of the NACA cowling, which reduced drag of the engine tremendously. The Boeing 247 was the first airplane to use the NACA cowling and a fillet between the wing and body.

Victory concluded by saying he sees no hope for the United States unless we are committed to a policy of supremacy in the air.

ELAINE GETHING
Secretary

STUDENT BRANCHES

The Pennsylvania State University

The first fall meeting was held September 21, with 60 aeronautical engineering students present. Richard Moore welcomed the new students and John A. Fox, Faculty Adviser, outlined the organization and functions of the IAS.

James Tedeschi was elected Chairman and Dave Brode, Vice-Chairman.

JOEL PETERSON, *Secretary*

University of Colorado

The Aeronautical Engineering Department of the University of Colorado is moving—moving up, that is! Statistics compiled by Walter McKay, AFIAS, Professor of Aeronautical Engineering at Massachusetts Institute of Technology, show that the University of Colorado now ranks eighth among U. S. colleges in the number of undergraduates studying aeronautical engineering, and ninth in total aeronautical engineering enrollment.

The most interesting fact (to us) in McKay's report is that the University of Colorado is No. 1 nationally in rate of increase of enrollment over a 5-year period through 1954. The Aeronautical Engineering Department shows "a 60 per cent increase in the fall of 1954 over the previous 5-year average." This is more than twice the rate of growth of any of the other top ten aeronautical engineering schools, according to the booklet, which is entitled "Enrollment in Aeronautical Engineering in United States Colleges."

▶ The Student Branch held its first fall meeting September 27 with Chairman Paul Lord presiding. There were 73 members and guests present. We have 82 members this year.

The second meeting was held October 5 with 48 in attendance. After the business meeting, six students who had worked in the aircraft industry during the summer gave 15-min. talks. They described the type of work they had done, the company's present activities and products, the work done by other departments, and employee-management relations. Companies represented in the talks were Douglas Aircraft Company, Inc.; North American Aviation, Inc.; Lockheed Aircraft Corporation; The Cessna Aircraft Company; and Allison Division of General Motors Corporation.

HAROLD J. BARTLESON, *Secretary*

University of Kansas

George G. Edwards, of the NACA's Ames Aeronautical Laboratory at Moffett Field, Calif., spoke at the first fall meeting of the Student Branch on October 4.

Describing the National Advisory Committee for Aeronautics as the world's largest aeronautical research group, he exhibited colored slides showing research facilities at Ames Laboratory. He answered a number of questions concerning research work as a Civil Service employee of the Federal Government.

MARJORIE HEARD, *Secretary*

University of Notre Dame

The first meeting of the fall semester, held in the Aeronautical Engineering Building September 29, was called to order by Chairman Joseph Poynton. He introduced the other new officers: Robert Lewis, Vice-Chairman; Raymond J. Mauren, Secretary; Ronald Witt, Treasurer; and F. M. N. Brown, Faculty Adviser.

The Chairman described the aims of the IAS Student Branch and the Faculty Adviser spoke on the scope and future of the aeronautical engineering profession. About 50 students attended.

RAYMOND J. MAUREN, *Secretary*

University of Oklahoma

Chairman Phil E. Fisher opened the October 4 meeting with a short talk explaining the purpose of the IAS Student Branch and the qualifications of membership. Faculty Adviser L. A. Comp discussed IAS functions on a national scale. Following the talks, a *March of Time* film showing new Air Force planes was presented.

THOMAS B. SHOEBOTHAM, *Secretary*

University of Wichita

The Student Branch met October 5 to hear Charles Seibel, Head of the Helicopter Division of The Cessna Aircraft Company, speak on Cessna's research and development in the rotary-wing field.

After showing an introductory film, *The Story of the Helicopter*, the speaker narrated a company film describing the development of the CH-1, Cessna's first helicopter, which is now flying experimentally. He pointed out some of the unusual design problems and their solutions. Helicopter performance and some of the difficult tasks the machines can perform were discussed.

Chairman Fred Marchand presented the Student Chapter's Scholastic Award to Dale Cooley. This is given to the member with the best record during his junior and senior years.

Members were urged to prepare papers for the IAS Student Paper Competitions. Samples of prize-winning papers were shown. A Program Committee was appointed to invite speakers and arrange field trips.

DUANE CHICHESTER, *Secretary*

(*IAS News continued on page 67*)

• • •

Attention Members!

All members of the Institute are invited to submit material concerning their activities for publication in the "News of Members" columns of the *Aeronautical Engineering Review*.

MEMBERS ELECTED

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the Review.

Elected to Associate Fellow Grade

Golden, Jack, B.A. in Ae.E., Dir., Turbo Engrg. Dept., American Machine & Foundry Co.

Gray, W. H., B.S. in Ae.E., Aero. Research Scientist, Langley Aero. Lab., NACA.

Hilton, W. F., D.Sc. in Aeronautics, Chief Aerodynamicist, Sir W. G. Armstrong Whitworth Aircraft, Ltd.

Sosnoski, Harry A., M.S. (Aero.), Capt., USN (Ret.); Aviation Advisor to the Pres., Olin Mathieson Chemical Corp.

Transferred to Associate Fellow Grade

Bloch, Rene M., M.S., In charge of R&D, Service Technique & Aeronautique, French Naval Aviation.

Oliver, Thomas K., Sc.D. in Field Instrumentation, Major, USAF; Asst. Prof., USAF Institute of Technology.

Zupanick, Joseph E., M.Sc. in Ae.E., Engrg. Sect. Head for Preliminary Design & Fundamental Studies, Sperry Gyroscope Co.

Elected to MEMBER Grade

Aarnaes, Morten H. K., Dipl. Engr., Design Engr. "A," Lockheed Aircraft Corp. (Burbank).

Arnell, Walter, B.Sc.Ae.E., Instructor, Univ. of Southern California.

Bergstrom, John S., Sr. Design Group Engr., Fuselage Group, Convair, San Diego, A Division of General Dynamics Corp.

Cregut, Peter, B.S., V-P, Gyromechanisms, Inc.

Culnan, David E., M.S.E.E., Research Engr.—Guided Missiles, Boeing Airplane Co. (Seattle).

De Bolt, Arthur R., Col., USAF; Asst. to the V-P, North American Aviation, Inc. (Los Angeles).

Doyle, Joseph A., V-P & Dir., Aero Div., Sun Electric Corp.

Edwards, Craig H., M.E., Mgr. West Coast Office, New York Air Brake Co.

Fabian, Charles B., B.A., Flight Test Analysis Engr., Lockheed Aircraft Corp. (Burbank).

Friccero, William J., B.S. Math., Aero. Engr., Component Test Dept., Propulsion Div., BuAer, U.S. NAMTC.

Hagenmaier, Carl F., M.S. in Ae.E., Military Coordinator—Military Requirements, Lockheed Aircraft, Inc. (Van Nuys).

Helene, Holger, B.S., Aero. Engr., assigned to Douglas Aircraft Co., Inc., BuAer.

Humphrey, James B., A.B., Chief Test Engr., Hydra-Electric.

Hunt, William R., B.M.E. (Applied Sc.), Engrg. Designer "A," Boeing Airplane Co. (Seattle).

Kennedy, Ernest D., M.S., Thermodynamics Engr., Convair, San Diego, A Division of General Dynamics Corp.

Kenyon, David H., Military Sales Engr., Lockheed Aircraft Corp. (Burbank).

Krop, Martin A., S.M. in Ae.E., Engr.—Aerodynamics, Aerophysics Lab., North American Aviation, Inc. (Downey).

Lawlor, Ernest F., Sr. Scientific Officer, Aerodynamics Dept., Royal Aircraft Establishment (England).

Nauschuetz, Peter, Dipl. Ing., Sr. Aerodynamicist, Ingenieur Buro Dipl. Ing. Bolkow.

O'Brien, Vivian, M.S. in Ae.E., Research Staff Asst.—I.C.R. Research in Fluid Mechs., Johns Hopkins Univ.

Oliver, Edward P., B. of Ae.E., Asst. Group Head, RAND Corp.

Richardson, Lynn D., B.S., V-P—Military Sales, Beech Aircraft Corp.

Richardson, William M., A.B., Wash. Rep., The Ramo-Wooldridge Corp.

Robinson, James B., III, M.S. in Ae.E., Major, USAF; Aero. Engr.—Field Rep., ARDC, Washington Air Force Development Field Office.

Robinson, William C., B.Sc. in Ae.E., Supervisory Proj. Engr., Kelly AFB.

Schroter, Albert R., M.E., Assoc. Engr., Missile Systems Div., Lockheed Aircraft Corp. (Van Nuys).

Stelzner, William B., Jr., B.S.M.E., Specialist—Turbine Driven Aircraft Accessories, General Electric Co. (Dayton).

Tanalski, T. T., B.S.C.E., Sr. Struct. Engr., Convair, San Diego, A Division of General Dynamics Corp.

Thomson, Arthur R., M.S.E., Proj. Engr., Thompson Products, Inc.

Van Der Bliek, Jacob, E.E., Design Engr., Lockheed Aircraft Corp. (Burbank).

Van Salter, Marvin M., A.A. & B.A., Production Test Pilot, Northrop Aircraft, Inc.

Zeitlin, Alexander, M.S.M.E., Pres., Engineering Supervision Co.

Transferred to MEMBER Grade

Beller, William S., M. of Ae.E., Managing Editor, *Aero Digest.*

Brunk, James E., B.S., Aerodynamicist, Pastushin Aviation, Inc.

Campbell, James R., B.S. in Ae.E., Stress Engr., Marquardt Aircraft Co.

Coward, Kenneth S., B.S. in Ae.E., Design Engr. "A," Ryan Aeronautical Co.

Gill, John D., M.S. in M.E. (Propulsion), Asst. Prof.—Mechanical Engrg., School of Engrg., Univ. of Miami.

Hunter, Robert F., B.S., R&D Engr., Shafer Bearing Div., Chain Belt Co.

Johnson, Charles A., B.S.Ae.E., Reverse Thrust Devel. Group Leader, Turbojet Components Dept., Marquardt Aircraft Co.

Layton, Donald M., M.S.E., Lt., USN; Electronics Officer—General Supervision of Maint., Airship Squadron Four.

Love, Sol, B.S. in Ae.E., Proj. Engr., Chance Vought Aircraft, Inc. (Dallas).

McEwan, James D., B.S., Asst. to Chief Test Engr., Radioplane Co.

McWilliams, Bayard T., M.S. in Ae.E., Product Application Engr., Wright Aero. Div., Curtiss-Wright Corp.

Penland, Jim A., B.S. in M.E. (Aero.), Aero. Research Scientist, NACA, Langley AFB.

Pines, Samuel, M.S. in Math., Chief Dynamics Engr., Republic Aviation Corp.

Rall, Frederick T., Jr., M.S., Proj. Engr.—Internal Aerodynamics, Hq. WADC, Wright-Patterson AFB.

Schmit, Lucian A., M.S., Research Engr., Project Leader, Aeroelastic & Struct. Research Lab. Massachusetts Institute of Technology.

Elected to Associate Member Grade

Brooks, Henry T., B.S., Engrg. Administrative Supvr., Engrg. Dept., Convair, San Diego, A Division of General Dynamics Corp.

De Haas, Hank, Inspector—Quality Control, Missile R&D Lab., Hughes Aircraft Co.

Farrell, Cecil A., Engrg. Technician, Fleet Manufacturing, Ltd.

Kane, W. Jerome, B.A., Asst. Sales Mgr., Boeing Airplane Co. (Seattle).

Riddle, John W., Field Service Rep., Allison Div., General Motors Corp.

Ruprecht, Fred A., Parachute Lab Superintendent, Cook Research Lab.

Williams, Thomas, Major, USAF; Assigned to Command & Staff College, Maxwell AFB.

Transferred to Associate Member Grade

Derrick, Irvin H., Capt., USAF; Contracting Officer, American Embassy, European Office, Air R&D Command (Brussels).

Elected to Technical Member Grade

Bauer, Vernon F., Stress Engr., Aircraft Div., Rheem Manufacturing Co.

Delaney, Edward G., B.S. in M.E., Experimental Engr., Allison Division, General Motors Corp.

Dording, James P., B.S.M.E., Tech. Engr.—Small Aircraft Engines, General Electric Co. (Lynn).

Evans, R. Bryce, B.S. (Aero.), Missile Test Analyst, Convair, Pomona, A Division of General Dynamics Corp.

Fox, John E., Aircraft Design Draftsman, Wing Struct. Sect., Saunders-Roe, Ltd. (England).

Hansen, Ramon T., Jr., B.S. Industrial Engrg., Sr. Draftsman, Power Plant Group, Goodyear Aircraft Corp.

Laich, Alberto L., Gen. Mgr. & Partner, Laich & Co.

Levantine, Allan D., A.A., Design Engr.—Mechanical, Litton Industries of California.

Lichtman, Eugene A., B.S.M.E., Mechanical Engr., U.S. Naval Turbine Test Station (Trenton).

Lowe, Gideon C., Jr., A.B., Service Engr. (Publications), Lighter-Than-Air-Div., Goodyear Aircraft Corp.

Mason, Earl W., B. of Ae.E , Jr. Engr., Douglas Aircraft Co. (Santa Monica).

McAtee, William C., B.S.E.E., Field Engr., Aero. Div., Sperry Gyroscope Co.

Miller, Ralph E., Jr., M.S.C.E. (Struct. & Math.), Stress Analyst, Boeing Airplane Co. (Seattle).

Squire, Leonard C., B.Sc., Scientific Officer, Ministry of Supply, National Aero. Establishment (England).

Tzantzos, George J., B.S.M.E., Asst. Engr., Armour Research Foundation.

Watson, Walter W., Jr., B.S. in M.E., Design Engr., Convair, Fort Worth, A Division of General Dynamics Corp.

Transferred to Technical Member Grade

Allen, Larry E., B.S., Assoc. Engr.—Stress, Lockheed Aircraft Corp. (Burbank).

Baham, Mary L., Engrg. Asst., Northrop Aircraft, Inc.

Billings, Ralph B., B.S., Flight Test Engr., Allison Div., General Motors Corp.

Brubaker, David, B.S. Liberal Arts, Data Reduction Trainee, McDonnell Aircraft Corp.

Converse, Court B., B.S. in A.E., Aerodynamicist, Grumman Aircraft Engineering Corp.

Crogan, Leonard E., B.S. in Ae.E., Jr. Prof. Engr., NOL (Silver Spring).

Cutler, William, B.A.E., Engrg. Trainee, Republic Aviation Corp.

Easterbook, William G., B.S. in Ae.E., Jr. Engr. "B," Boeing Airplane Co. (Seattle).

Emory, John M. G., Jr., B. of Ae.E., Test Engr.—Trainee, Pratt & Whitney Aircraft Division of United Aircraft Corp.

Fleming, Bruce S., B.M.E., Research Asst.—Engrg., Ord. Research Lab., Physics Dept., Univ. of Virginia.

Forster, Allan, B. of Ae.E., Propulsion Engr., Grumman Aircraft Engrg. Corp.

Fulton, Graham B., B. of Ae.E., Research Asst., Rensselaer Polytechnic Institute.

Gauthey, Charles E., Jr. Engr.—Design, North American Aviation, Inc. (Los Angeles).

Glowczwski, Robert V., B.S., Engr.—General Design Work, McDonnell Aircraft Corp.

Greene, Donald L., B.S.E., Ens., USN; Student Pilot, NAS, Pensacola.

Hall, Howard H., B.S. in Ae.E., Enlisted Personnel, U.S. Army.

Hines, Lawrence D., B.S.A.E., Jr. Engr., Northrop Aircraft, Inc.

Horowitz, Abraham, B. of Ae.E., Loads Engr., McDonnell Aircraft Corp.

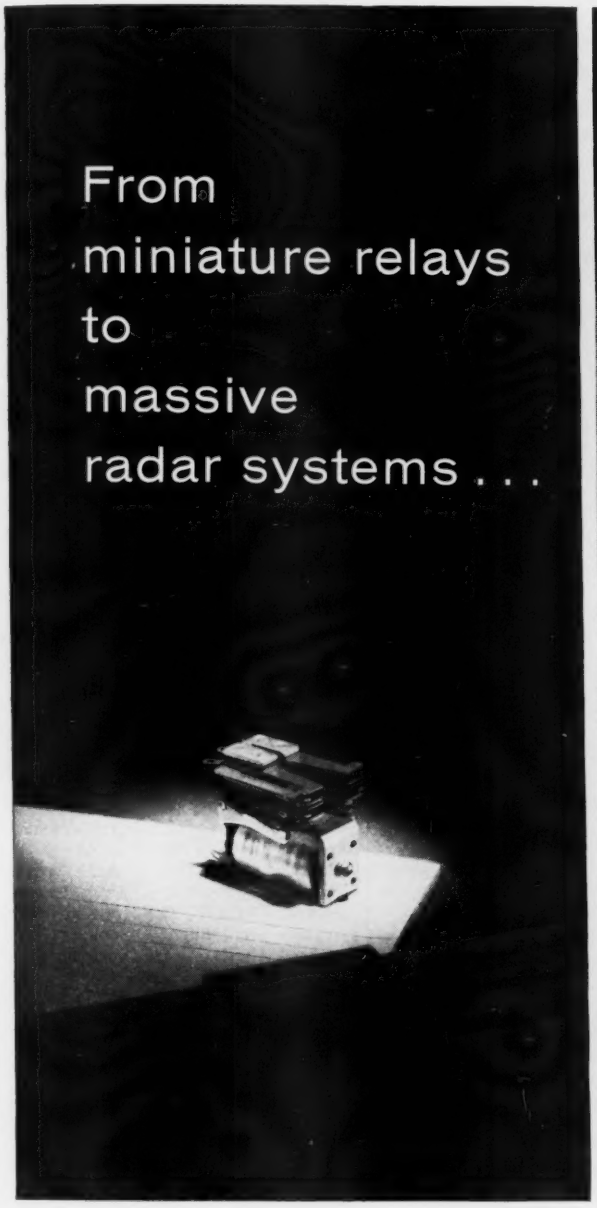
Jackson, Harry, B. of Ae.E., Jr. Design Engr., North American Aviation, Inc. (Los Angeles).

James, George T., Jr., M.S. in Ae.E.; Ae.E., Capt., USAF.

Jaremenko, Igor M., B.S. in M.E., Design Engr., LML Engineering Manufacturing Corp.

Jarymowycz, Michael I., B. of Ae.E., Graduate Student, Institute of Air Flight Struct., Columbia Univ.

Kaiser, Robert L., B.S., Flight Test Analyst "A," Douglas Aircraft Co. (Santa Monica).



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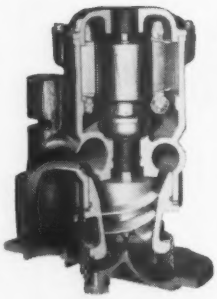

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Kelley, Gilbert H., B.Sc. in Engrg., Test Engr., Fairchild Airplane & Engine Corp.

Koyanagi, Frank S., Jr. Engr.—Design, North American Aviation, Inc. (Inglewood).

Laszewski, Marion M., B. of M.E., Struct. Engr., Bell Aircraft Corp.

Marks, Ronald S., B.S. in Aeronautics, Flight Test Analyst, Douglas Aircraft Co., Inc. (Santa Monica).

McCarthy, Carlisle J., B.S. in Ae.E., Airplane Design Engr., McDonnell Aircraft Corp.

McClinton, Robert, B.A.E., Jr. Engr.—Struct., North American Aviation, Inc. (Columbus).

McKinney, James D., B.S. in Ae.E., Ens., USN; Student Naval Aviator, U.S. Naval Air Basic Training Command, NAS.

Meier, James C., Mechanical Engr., WADC, Wright-Patterson AFB.

Mellish, Joseph A., B.S., Jr. Engr.—Aerodynamics, North American Aviation, Inc. (Columbus).

Morelewski, Joseph J., B.S.E. (Ae.), Assoc. Engr., Lockheed Aircraft Corp. (Burbank).

Moyer, James R., B.S., Aerodynamicist (F3H-2N Group), McDonnell Aircraft Corp.

O'Connor, John A., B. of Ae.E., Engr., General Electric Co.

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Aerodynamics

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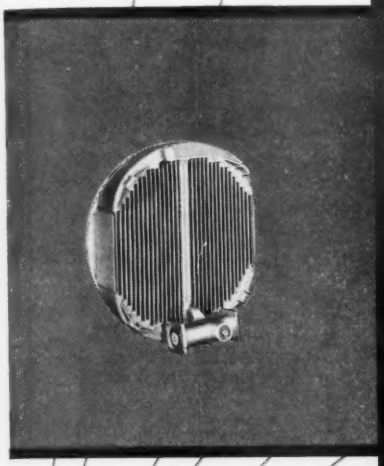

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Variable Sweep for the Extension of the Speed Range. L. E. Baynes. *Aeronautics*, Sept., 1955, pp. 60–65. Analysis includes results of investigations on longitudinal and lateral maneuvering control free of compressibility effects or aeroelastic deformations.

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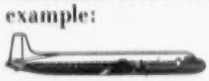

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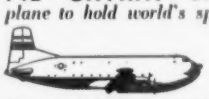

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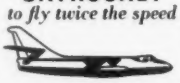

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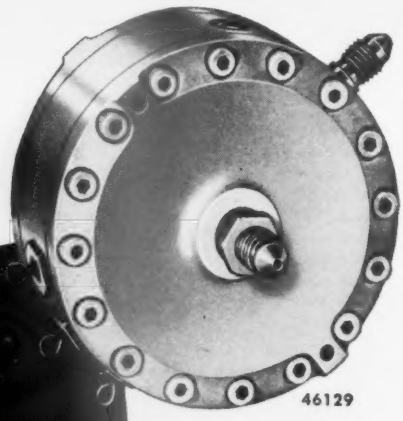

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46118

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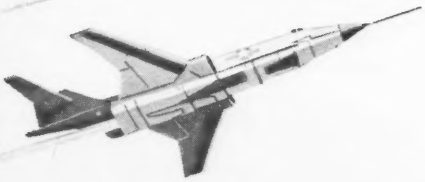

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2. Altitude: No specific limitation.
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5. Pressure Ranges (operating):
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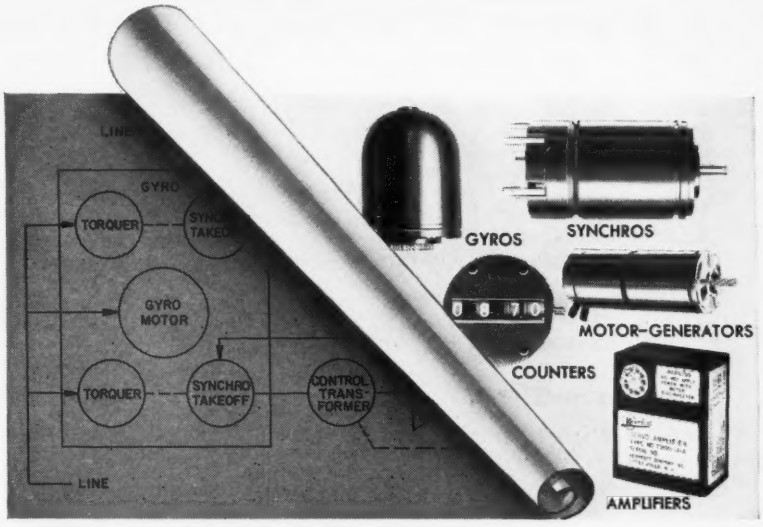

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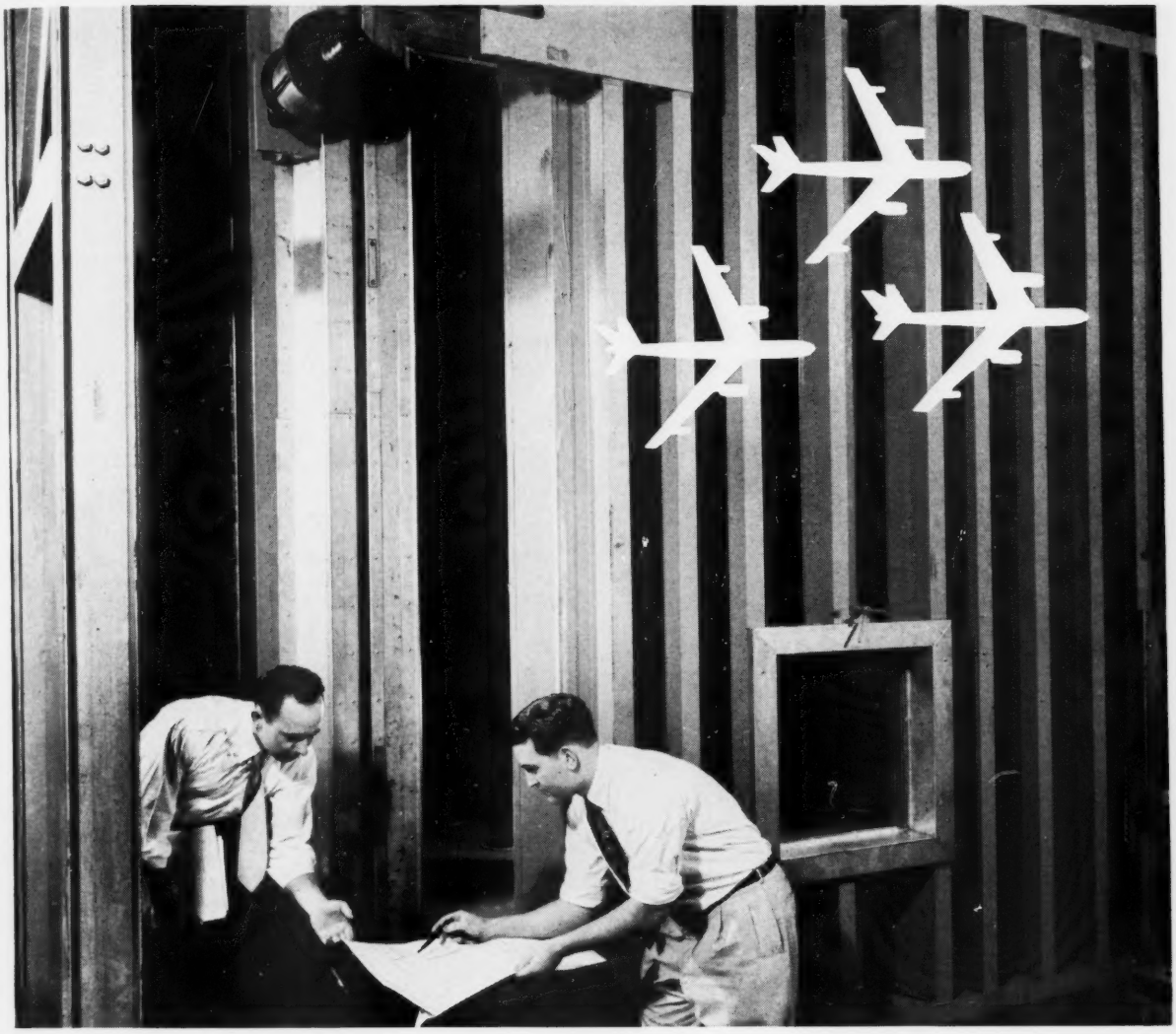

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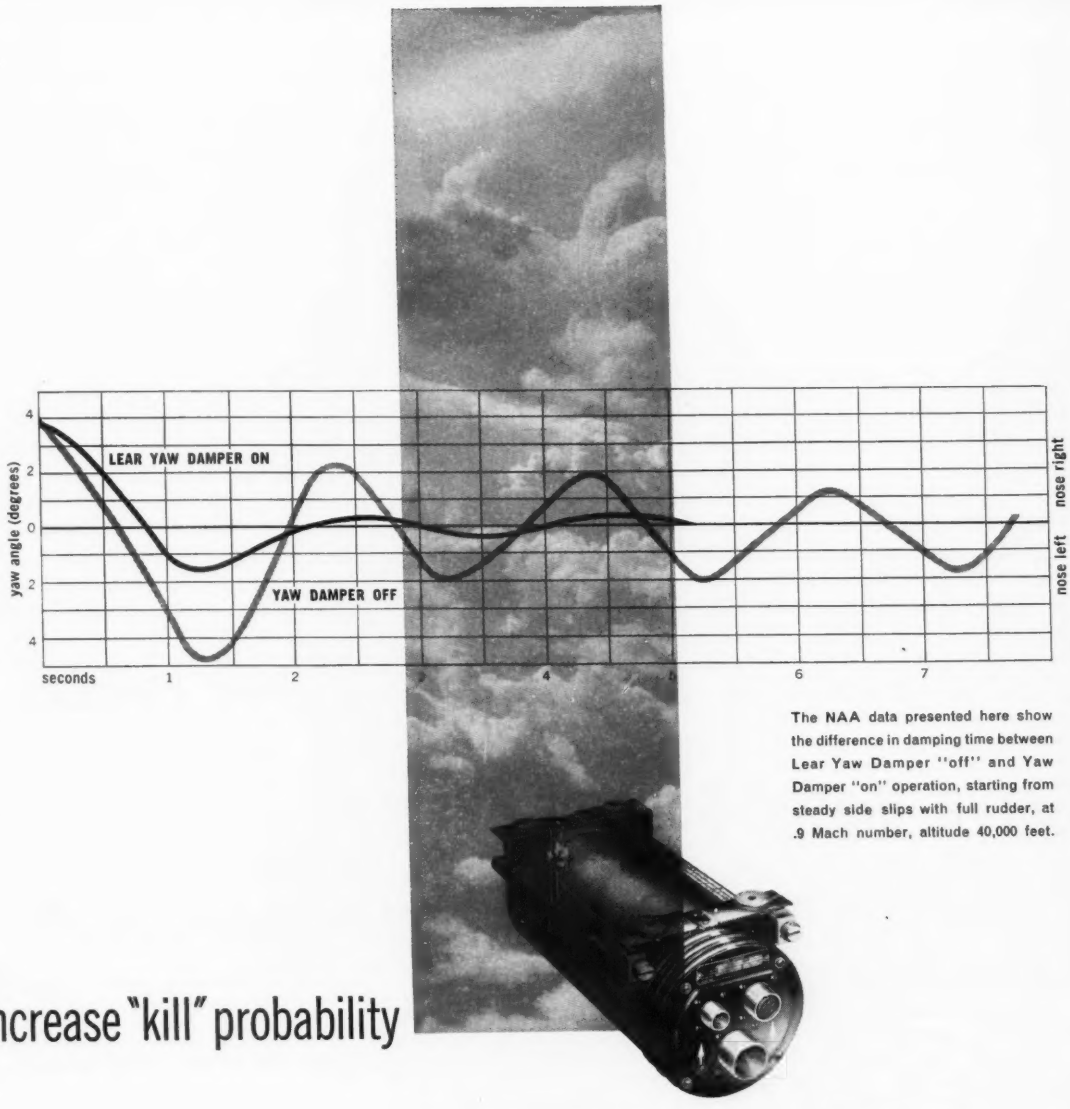

The NAA data presented here show the difference in damping time between Lear Yaw Damper "off" and Yaw Damper "on" operation, starting from steady side slips with full rudder, at .9 Mach number, altitude 40,000 feet.

to increase "kill" probability

Weapon system design combines many arts for the purpose of annihilating the enemy. The spectacular stabilizing effect of the Lear Yaw Damper on the flight path of the F-86D Sabre is shown in the above curves prepared by North American Aviation, Inc., for the enlightenment of fighter pilots. "From these data," says NAA, "it is clearly seen why the yaw damper is an essential device to make your airplane a more effective and efficient rocket firing platform."

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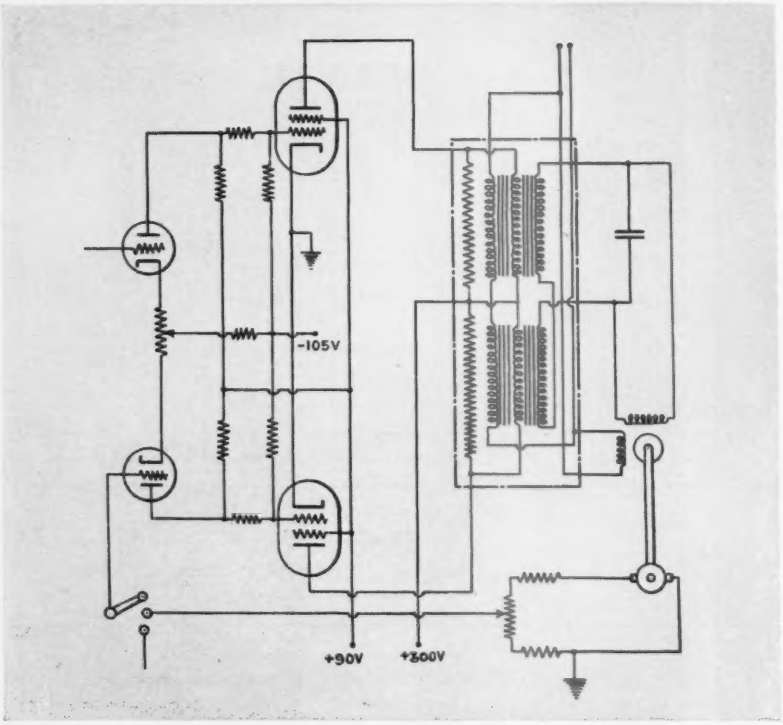

Servo Motor Control System

Most engineering ingenuity concentrates not on basic principles, which are relatively simple, but on the fine details that make the difference between good and poor design, between high and low cost, or between efficient and inefficient component arrangement. For instance, the motor control system patented by the Ford Instrument Company. The purpose of the system is to provide a sensitive control system to make an induction motor respond accurately to a relatively small reversible input signal. This system employs saturable-core transformers to combine the sensitivity of vacuum tube amplifiers with the high power-carrying capacity of saturated-core devices. This also facilitates the problem of matching the motor impedance with that of the amplifier.

In the circuit shown the first pair of tubes act as a phase inverter, with the control signal applied to the grid of one inverter tube. The feedback signal, produced by a d-c generator coupled to the controlled motor, is applied to the inverter tube. The output of the inverter is the signal of the servo loop. The second pair of tubes acts as a driver-stage for the saturated transformers that supply one winding of the controlled two-phase induction motor; the other motor winding is connected to the power line.

This is typical of the things Ford engineers do . . . every day. If you have a control problem it will pay you to talk to the Ford Instrument engineers.

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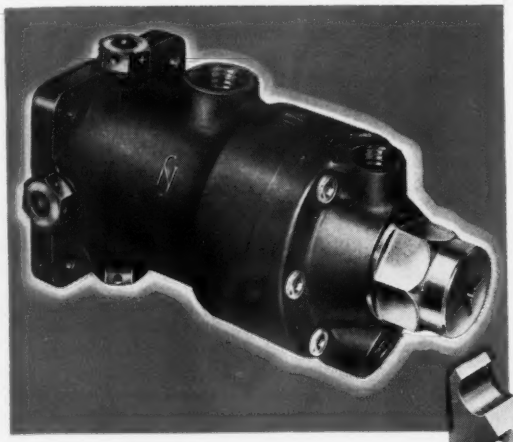

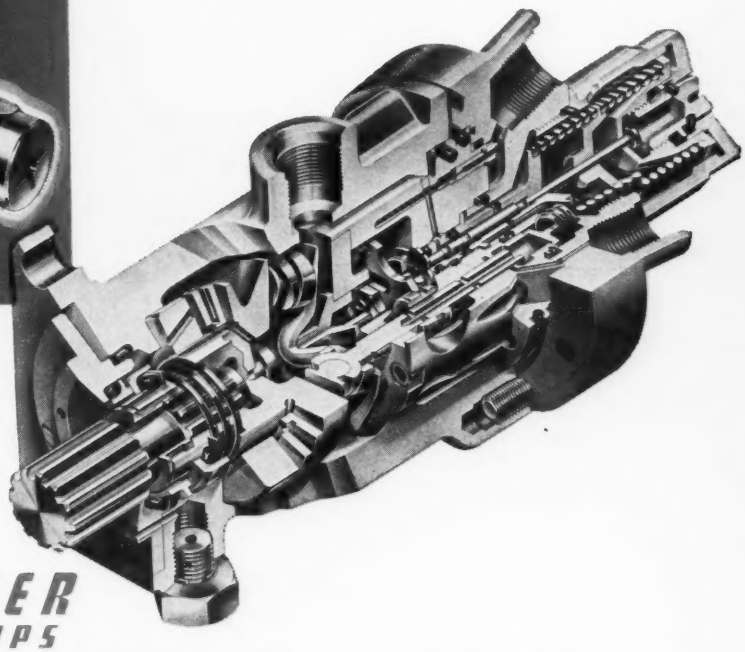

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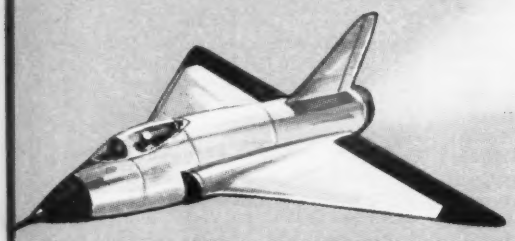

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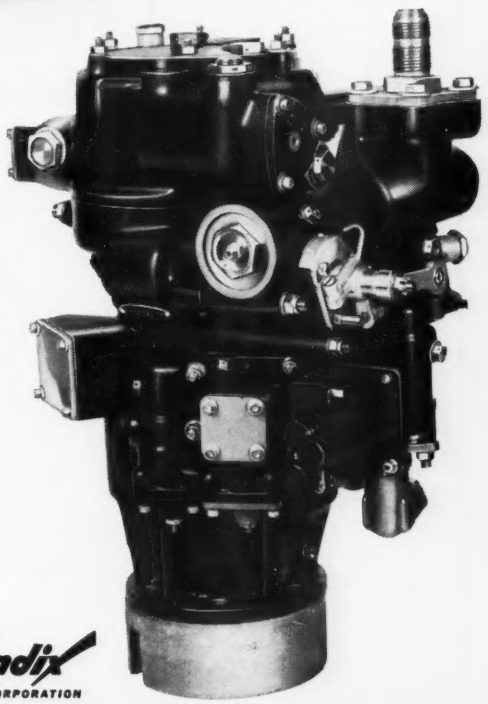

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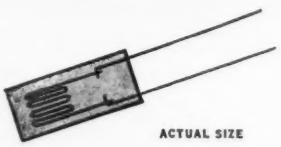

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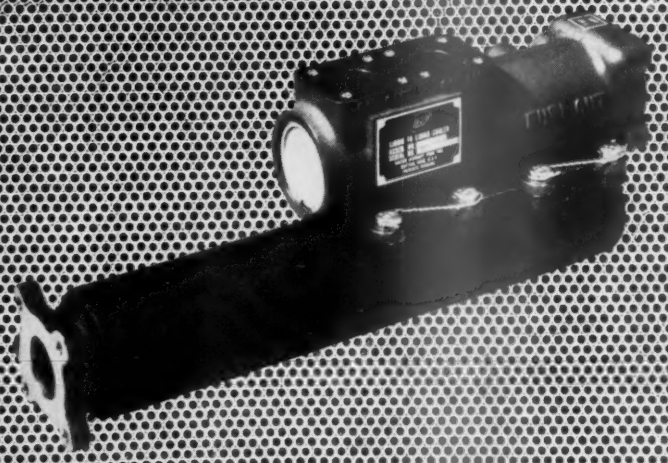

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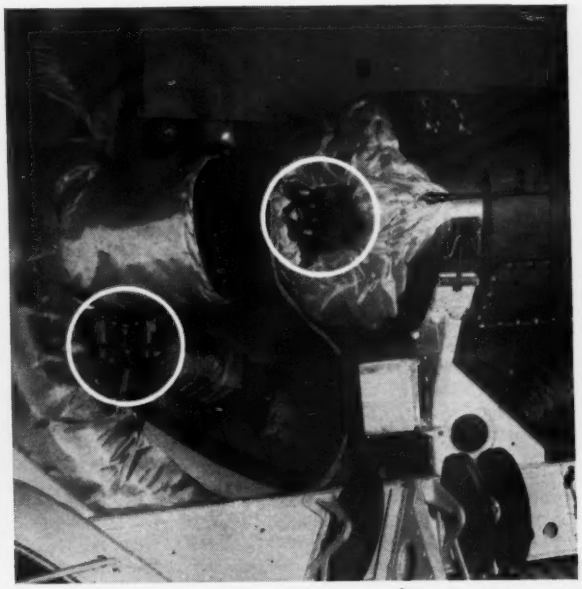

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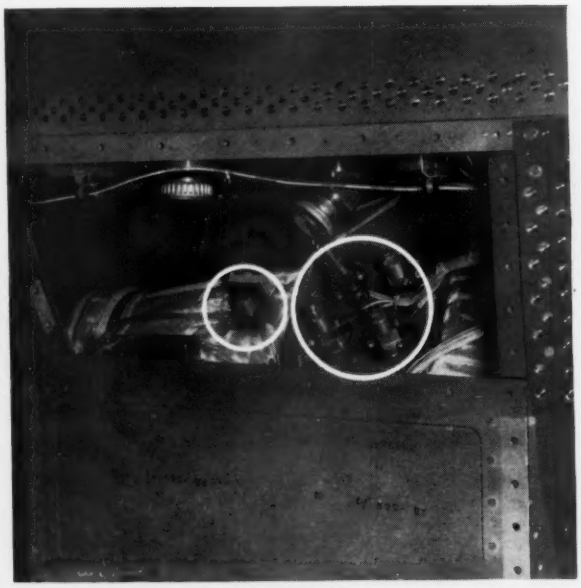

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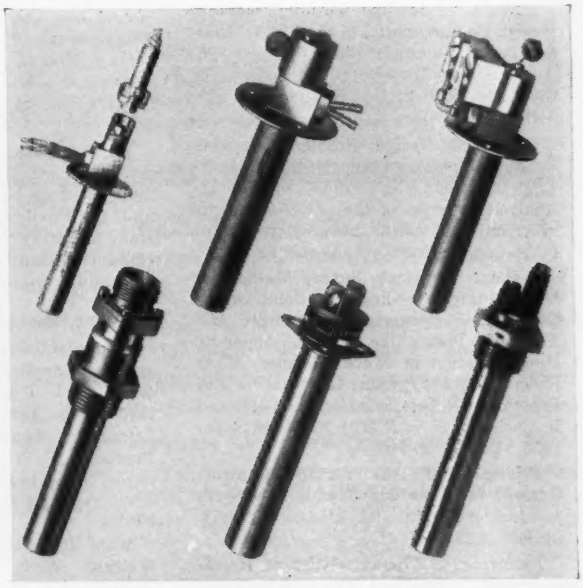

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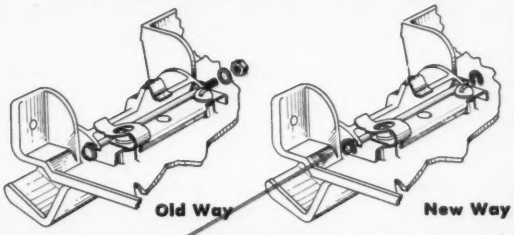

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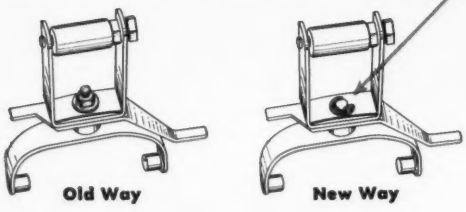

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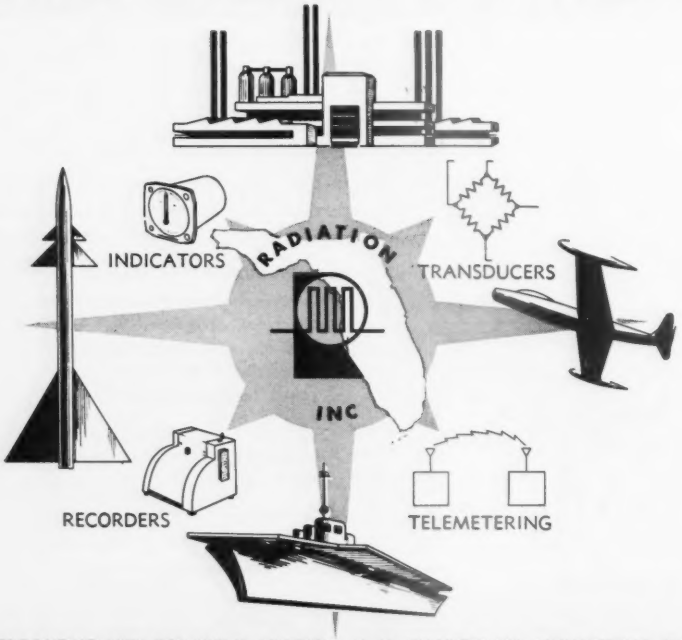

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Burton Erickson, Alexander Chwick, and N. J. Hoff. *U.S., NACA TN 3493*, Sept., 1955. 20 pp. 19 refs. Tests on aluminum alloy columns subjected to constant loads at elevated temperatures, with emphasis on the determination of the influence of initial deviations from straightness upon the critical time of the column.

Lateral Buckling of Asymmetrical Beams. H. L. Langhaar. *J. Appl. Mech.*, Sept., 1955, pp. 335, 336. Simplified theory for the conditions of beams under the action of uniform bending moments and axial thrusts.

The Stresses in a Built-up Girder Subjected to a Concentrated Load. E. W. Parkes. *Proc. Royal Soc. (London), Ser. A*, Sept., 6, 1955, pp. 379–387. Experimental investigation at the Coll. of Aeronautics, Cranfield, of stresses in a uniform built-up girder consisting of a web of constant thickness elastically connected to two similar flanges obeying the Bernoulli-Euler theory of bending.

The Ultimate Strength of Multiweb Box Beams in Pure Bending. Robert A. Needham. *J. Aero. Sci.*, Nov., 1955, pp. 781–786. Development of a method to predict the bending strength, with a comparison between the theoretical and test results based on an analysis of 49 beams of 75S-T6 sheet.

Connections

Investigation on the Strength of Redux Bonded 75 S-T6 Clad Simple Lap Joints and of 24 S-T Lugs at Rapidly Applied Loads. J. P. Benthem and G. de Vries. *Netherlands, NLL Rep. S.466*, June 15, 1955. 18 pp.

Cylinders & Shells

The Accuracy of Donnell's Equations. N. J. Hoff. *J. Appl. Mech.*, Sept., 1955, pp. 329–334. Comparison of the solutions for small deformations of perfectly elastic thin-walled circular cylindrical shells with those obtainable from the Flügge equations.

Simplified Formulas for Boundary-Value Problems of the Thin-Walled Circular Cylinder. Frederick V. Pohle and S. V. Nardo. *J. Appl. Mech.*, Sept., 1955, pp. 389, 390.

Elasticity & Plasticity

Les Déformations Développables des Tôles Minces. L. Kirste. *Tech. et Sci. Aéronautiques*, No. 3, 1955, pp. 192–194. In French. Fundamental behavior in the deformation pattern of thin sheets, with relevant examples for plates, cones, and cylinders.

On the Bases of the Theory of Non-Homogeneous Elasto-Plastic Bodies. I. W. Olszak. *Bul. Acad. Polonaise Sci. (Warsaw)*, No. 2, 1955, pp. 45–49. 17 refs.

On the Stretching of an Unbounded Disk with a Central Hole of Different Elasticity. F. Szelągowski. *Bul. Acad. Polonaise Sci.* (Warsaw), No. 2, 1955, pp. 79–84. Analytical method based on the Lamé formulas for the problem of stress and strain distribution in a circular hole.

Der Spannungs- und Verschiebungszustand drehsymmetrischer Membrane mit beliebig gekrümmter Meridiankurve. D. Rüdiger. *Ingen.-Arch.*, No. 5, 1954, pp.

336–347. 12 refs. The stress and strain of a rotationally symmetrical membrane with any type of meridian curve as applied to the analysis of the boundary conditions of open shells with harmonic loading for infinitesimal deformations.

Strength Under Combined Tension and Bending in the Plastic Range. J. M. Frankland and R. E. Roach. *J. Aero. Sci.*, Nov., 1955, pp. 795–797.

Plates

Buckling of a Rectangular Plate Under Locally Distributed Forces Applied on the Two Opposite Edges. IV. Noboru Yamaki. *Tôhoku U. (Japan) Rep. Inst. High Speed Mech.*, No. 48, 1955, pp. 159–174.

Diffusion of Concentrated Axial End Loads into Cylindrical Panels by Elements of Constant Strength. F. Misztal. *Bul. Acad. Polonaise Sci.* (Warsaw), No. 2, 1955, pp. 71–78.

The Effective Width in the Plastic Range of Flat Plates under Compression. Appendix—Calculation of the Ultimate Compression Load with Respect to General Instability of a Panel with Stringers in the Direction of the Load. M. Botman and J. F. Besseling. *Netherlands, NLL Rep. S.445*, Sept., 1954. 34 pp. 29 refs.

Limits of Economy of Material in Plates. H. G. Hopkins and W. Prager. *J. Appl. Mech.*, Sept., 1955, pp. 372–374. 10 refs. Limit analysis for a simply supported circular plate under a uniformly distributed transverse load.

Note on the Bending of a Circular Plate Under Continuous Non-Normal Loading. K. I. McKenzie and M. Rothman. *J. RAeS*, Sept., 1955, pp. 632–635.

Wings

Les Ailes Haubannées de Grand Allongement. Maxime Robin. *Tech. et Sci. Aéronautiques*, No. 3, 1955, pp. 185–191. In French. Structural analysis of the relative merits of braced wings of great length in terms of stress-strain loading, torsion, bending, aerodynamic, and other factors.

An Approximate Nonuniform Bending Theory and Its Application to the Swept-Plate Problem. H. J. Plass, Jr. *J. Appl. Mech.*, Sept., 1955, pp. 383–388. Theoretical development to determine deflections and stresses in high-speed swept-back wings idealized as a homogeneous isotropic prismatic bar of the same cross section as the wing.

The Root Section of a Swept Wing—A Problem of Plane Elasticity. Appendix—Direct Solution of Boundary-Value Problem. B. C. Hoskin and J. R. M. Radok. *J. Appl. Mech.*, Sept., 1955, pp. 337–347. Investigation using the Muskhelishvili methods of the state of stress and deformation in an approximately square plate with rounded corners under certain shear loading and concentrated forces at the boundary.

La Statique de l'Aile en Flèche. Pol Bodet. *Tech. et. Sci. Aéronautiques*, No. 2, 1955, pp. 98–115. In French. Analysis of the problem of the static resistance and stress concentrations on swept-back wings, taking into account the elasticity parameters for the specific case of obliquely embedded long beams.

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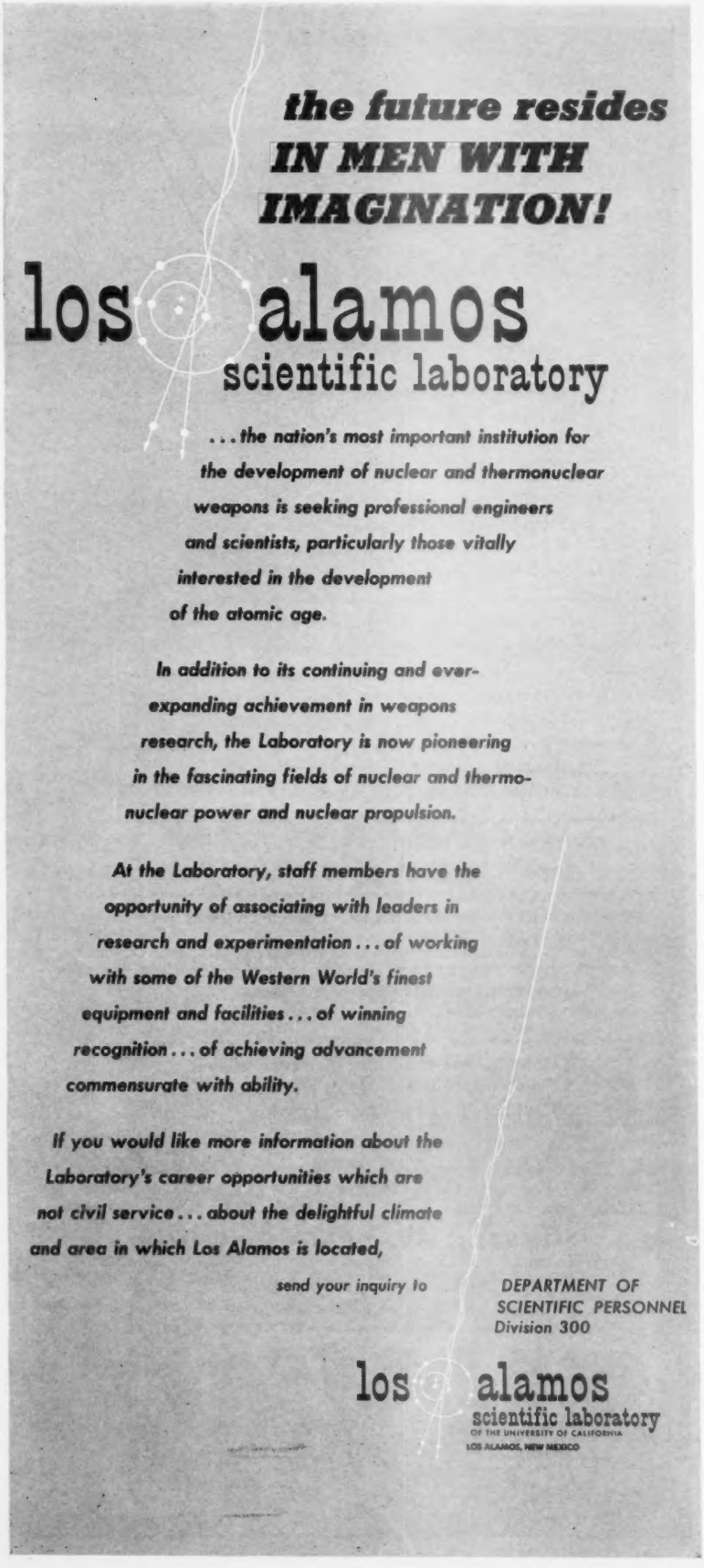
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Thermodynamics

Thermodynamic Properties of Gas at High Temperatures and Pressures. H. S. Tsien. *Jet Propulsion*, Sept., 1955, Part I, pp. 471, 472, 478.

Combustion

Bemerkungen zur Lumineszenzhypothese für Flammen. Eugen Sänger. *Weltraumfahrt*, Jan., 1954, pp. 4–9. 26 refs. In German. Analysis of the luminescence hypothesis for the principal behavior of flames in terms of heat-transfer, detonation-wave, chemical-exchange, and other parameters.

Effects of Attentuating Materials on Detonation Induction Distances in Gases. Marjorie W. Evans, Frank I. Given, and William E. Richeson, Jr. *J. Appl. Phys.*, Sept., 1955, pp. 1,111–1,113. Application to the problem of the initiation of detonation by shock waves.

General Enthalpy-Temperature-Entropy Diagram for Ideal Gases and Gas Mixtures up to 5000 K. W. Noeggerath. *Jet Propulsion*, Sept., 1955 Part I, pp. 454–462, 470. 16 refs.

Heat Transfer

Elementi di Gasdinamica delle Miscele. Gianni Jarre. *L'Aerotecnica* (Rome), June, 1955, pp. 137–143. In Italian. Includes an analysis of the molecular heat transfer.

Thermal Stresses in Rectangular Strips. II. J. S. Born and G. Horvay. *J. Appl. Mech.*, Sept., 1955, pp. 401–406. Extension of the theory of step-function temperature distribution to the cases of temperature break using the Fourier integral, the biharmonic eigenfunction-expansion, and self-equilibrating function-expansion methods.

Vertical Take-Off Aircraft

Design Aspects of Bell Aircraft VTOL Airplane. James A. O'Malley, Jr. *Can. Aero. J.*, Sept., 1955, pp. 100–102. Appraisal of developmental problems, including design philosophy, construction, testing, operation, and stability and control.

Experiments in Powered Lift. F. J. Grose. *Aeronautics*, Sept., 1955, pp. 76–78. Experimental investigation of VTO design and adaptation problems, with an appraisal of potentialities.

Water-Borne Aircraft

Hydrodynamic Pressure Distributions Obtained During a Planing Investigation of Five Related Prismatic Surfaces. Walter J. Kapryan and George M. Boyd, Jr. *U.S., NACA TN 3477*. Sept., 1955. 82 pp. 12 refs.

Hydro-Ski Development at Saunders-Roe. I. P. G. Fielding. *Saro Prog.*, Fall, 1955, pp. 12–15. Review of hydrodynamic engineering and problems, with results of design tests on models.

(*Continued on page 116*)

Aeronautical Reviews — BOOKS

Selected Papers on Engineering Mechanics

A Tribute to Theodore von Kármán from Students and Associates of the Aachen Period. Editors: G. Gabrielli, F. N. Scheubel, and F. L. Wattendorf. London, Butterworths Scientific Publications; New York, Academic Press, Inc., 1955. 186 pp., illus., diagrs.

This volume represents a tribute to Dr. Theodore von Kármán from a group of former students and associates of the Aerodynamics Institute at the Technische Hochschule, Aachen, during the period 1912 to 1931. This book was initiated and planned by Dr. B. G. Dirksen, formerly an assistant to Dr. von Kármán at Aachen. After Dr. Dirksen's death in 1951 the continued work on this book was taken over by an editorial board consisting of Dr. Gabrielli for the Italian papers, Dr. Scheubel for the German papers, and Dr. Wattendorf for those written in English.

The scope of the papers covers the following topics:

Airplane Design:

G. Gabrielli, "A Method for Determining the Wing Area and Aspect Ratio in Aircraft Design." This paper covers the airplane performance equations and in addition introduces an empirical relation for the airplane weight breakdown. From these equations the author shows how it is possible to develop the most convenient compromise in the overall design.

G. V. Lachmann, "The Case for Laminarization." This paper covers a review of theory and experiments and a discussion of the prospects for maintaining a laminar flow on modern high-performance subsonic aircraft. He points out that the maintaining of laminar flow and the optimum design of an aircraft for incorporating laminar flow represent the only fundamental aerodynamic possibility for improving the economy of flight in the subsonic regime.

Dynamics:

R. Grammel, "Theory of the Self-Excited Unsymmetrical Gyroscope." This paper presents an integration of Euler's equations of motion for a gyroscope which has a constant applied moment. This problem is of considerable importance, for example, in the problem of a spinning rocket when the jet thrust is inclined to the axis of the missile.

Mechanical Engineering:

T. H. Troller, "Theoretical Aspects of Rock Breakup in Mining and Construction Work." This paper presents a review of the problem of rock breakup from the standpoint of energy consumption in terms of the size of the particles and the physical contents of the mineral. It is suggested that scientists with a knowledge of applied mechanics investigate this problem in view of its importance from the standpoint of human endeavor.

M. Hansen, "Flow and Heat Exchange in Blast Furnace Stoves." The author studies the flow characteristics including pressure losses and heat exchange in blast furnaces and points out certain relationships which were of significance in the choice of the brickwork for the checkering of a blast furnace.

F. Bollenrath and A. Troost, "The Effect of Size and Shape Upon Fatigue Strength." This paper briefly summarizes the author's research on the influence of size and shape of a structure on the fatigue strength.

Lorenzo Poggi, "The Theory of 'Semi-Static' Pressure Exchangers." This paper presents a theory of pressure exchangers which are devices that compress the fluid by a continuous pressure at the expense of the expansion of another fluid between the same pressure limits. Reference is made to the type of pressure exchanger originally devised by Labre with, however, some novel modifications proposed by the author.

Aerodynamics:

Frank L. Wattendorf, "Some Aspects of Three-Dimensional Flow in Turbomachinery." This paper first reviews some hitherto unpublished reports written by Dr. von Kármán during the period 1940 to 1942 which, because of their important pioneering nature, are reproduced in full as Appendices. These preliminary analyses stimulated much further work by Rannie, Marble, and other von Kármán associates.

It is shown that for combinations of low hub ratio and high stage pressure ratio, the axial velocity distortion may be strong enough to form a design limitation. In order to show the nature of such effects and discuss remedies, a simplified equation for radial pressure equilibrium is presented.

Methods of alleviation of axial velocity distortion are discussed, starting with the proposal to have a preliminary rotating stage, called an "inducer," which introduces in the flow an initial total head gradient of alleviating nature.

Finally, the importance is emphasized of developing a preliminary inducer stage for optimum combination of mass flow and stage pressure ratio. It is shown that if this can be accomplished in the preliminary stage, three-dimensional effects become much less important in the normal compressor stages and design conditions are less stringent.

For the case that a subsonic relative Mach Number is the limiting design condition, it is shown that gearing down the inducer is in a favorable direction, and an optimum solution is presented for the particular assumptions. If, however, such Mach Number limitations could be raised by suitable research, still more favorable solutions would be possible.

In the light of the importance of high-output compressors and the dearth of knowledge of three-dimensional flow effects, increased research in this field, both theoretical and experimental, is strongly advocated.

F. N. Scheubel, "Systems Whose 'Inertial' and 'Gravitational' Masses Are Not Identical." The author presents a discussion of the apparent mass problem and applies it to the case of:

(a) The descending parachute.
(b) The oscillations of a free balloon.
(c) The rolling of a ship.

A. Betz, "Analytical Treatment of Subsonic Flow in a Supersonic Region." The author considers the

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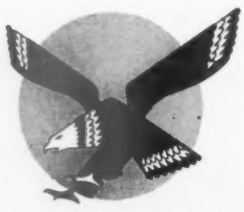

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potential flow problem for the motion of a compressible fluid past a body at sufficiently high speeds such that over portions of the body flow velocities are subsonic and over other portions they are supersonic. He outlines the analytical procedures for a study of this problem.

WILLIAM BOLLAY
President
Aerophysics Development Corporation

Book Notes

AERODYNAMICS

Fluid Mechanics. R. C. Binder. 3rd Ed. New York, Prentice-Hall, Inc., 1955. 388 pp., illus., diagrs. $7.65.

This is a completely new edition of a work originally published in 1943 and revised once before in 1949. Set in new type, with the chapters rearranged for more flexible use in the classroom, the book now consists of two parts. Part One treats of the basic relations of force, mass, and acceleration. Part Two discusses the application of these basic relations in current practice of fluid mechanics.

FLIGHT SAFETY

Survey of Research Projects in the Field of Aviation Safety; Fourth Annual Supplement. New York, The Daniel & Florence Guggenheim Aviation Safety Center at Cornell University, January, 1955. 98 pp. $2.00.

Following the format of previous annual supplements, this survey lists under one or more of some 60 subject headings the specific title, description, and sponsor of each research project pertaining to aviation safety. In a separate section those projects which were completed or discontinued during 1954 are listed in alphabetical order.

HUMAN ENGINEERING

Anthropometry and Human Engineering; A Symposium on Anthropometry, Human Engineering and Related Subjects Conducted by the AGARD Aeromedical Panel on 3 and 4 May 1954 in Scheveningen, The Netherlands. (AGARDograph No. 5.) London, Published for and on behalf of AGARD, NATO, by Butterworths Scientific Publications; New York, Interscience Publishers, Inc., 1955. 123 pp., diagrs. $3.00.

Contents: I, Anthropometry: (1) Body Measurements in Relation to Work Spaces in Aircraft, G. M. Morant. (2) Statistiques de Biométrie Medicale Elémentaire Relatives au Personnel Navigant de l'Armée de l'Air Française (Statistics of Elementary Medical Biometrics Relative to Navigation Personnel in l'Armée de l'Air Française), E. Ducros. (3) Sheldon Types and Success in Flight Performance, Johannes Dossing. Opening Discussion on the Above Papers (in French), E. Evrard.

II, Human Engineering: (1) Adapting the Aeroplane to the Pilot, W. K. Stewart. (2) Instrument Dials, Instrument Arrangement, and Cockpit Design, Walter F. Grether. (3) A Methodology for Instrument Display Design, G. W. Hoover. Opening Discussion on the Above Papers, H. P. Ruffell Smith.

III, Related Subjects: (1) Factors Affecting the Validity and Utility of Aeromedical Research Data, R. B. Payne. (2) The Establishment of a Longitudinal Study of the Medical and Psychological Aspects of the U.S. Naval Aviator, Ashton Graybiel. (3) Somatotyping, P. M. van Wulfften Palthe. (4) Human Factors in Aircraft Design, Morley G. Whillans.

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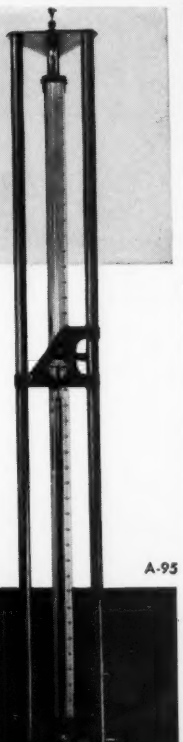

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MATHEMATICS

Die Differentialgleichungen der Technik und Physik (The Differential Equations of Technology and Physics). Wilhelm Hort. Edited by Alfred Thoma. 6th Ed. of Die Differentialgleichungen des Ingenieurs (Differential Equations for the Engineer). Leipzig, Johann Ambrosius Barth Verlag, 1954. 582 pp., diagrs. (In German.)

In this revised volume, no departures have been made from the plan of the previous (1950) edition, but the treatment of certain topics has been expanded. In Section 64, a discussion of the Riccati differential equation has been added, while Section 97, on induced oscillation, now includes the differential equation for finite amplitudes. The eight principal divisions of the text are as follows: Fundamental Considerations; Ordinary Differential Equations; Approximate Integration of Ordinary Differential Equations; Mechanical Integration of Differential Equations; Difference Equations; Partial Differential Equations; Principles of the Calculus of Variations; Introduction to the Theory of Linear Integral Equations.

MECHANICS

Mechanik; Bd. 3., Dynamik der Systeme (Mechanics, Vol. 3, System Dynamics). Hans Ziegler. Basel, Switzerland, Verlag Birkhauser, 1952. 396 pp., diagrs. Sw. fr. 46.80.

This is the final volume in a series of three concerned with the fundamentals of mechanics. Volume 1 treats the statics of rigid, fluid, and elastic bodies; Volume 2, the dynamics of rigid bodies. The first chapter of the present work deals with the dynamics of systems of rigid bodies, and here emphasis is placed on the development of the Lagrangian equations, which must be mastered by today's engineers. The second chapter is an introduction to the theory of oscillations with varying degrees of freedom. This chapter serves also to introduce the final section of the book, on continua, in which are developed the methods used in elastostatics, elastodynamics, and hydrodynamics. The author is Professor, Eidgenössische Technische Hochschule, Zurich.

MISSILES

Guidance. Arthur S. Locke and Others. (Principles of Guided Missile Design Series. Edited by Grayson Merrill.) Princeton, N.J., D. Van Nostrand Co., Inc., 1955. 729 pp., diagrs. $12.50.

A comprehensive treatment of the basic principles of missile guidance, and one in a series of volumes under the general editorship of a pioneer in the Navy missile program. The principal author is Associate Director of the Vitro Laboratories and has been engaged in missile guidance research for the past 10 years.

Contents: Fundamental Problems of Missile Guidance. Prior Developments. Terrestrial and Celestial References. Transmission of Radio Waves. Emission, Transmission, and Detection of the Infrared. Mathematical Groundwork. Servo System Theory. Tactical Considerations. Measurements of Missile Motion. Detection and Information Gathering. Target Considerations. The Analysis of Flight Paths. Prelaunching and Launching. The Missile Airframe. Economic Considerations. Missile Guidance Systems. Bandwidth Studies. Missile Guidance Bandwidth Studies. Simulation, Computation and Telemetry. The System Concept.

NAVIGATION

Air Navigation. P. V. H. Weems. Annapolis, Md. Weems System of Navigation, 1955. 473 pp., illus., diagrs. $6.00.

This fourth edition of the well-known manual, although shorter by over 100 pages, has been thoroughly revised to bring the text up to date,

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Standardization on certain methods and equipment has permitted the elimination of much obsolete material, making room for the inclusion of several new subjects. New chapters on Omnirange, Loran, radar, Consol, pressure pattern flying, and polar navigation reflect the developments of recent years. Also there is new material on flight planning and cruise control and a practical chapter entitled, "The Navigator at Work." The final chapter, "The Flight Navigator Examination," contains a sample examination, intended to typify the CAA Examination for unlimited certification. Brief reference is made in an appendix to the Q-Signal Code, radio astronomy, and space navigation. A bibliography is also provided.

POWER PLANTS

Gas Turbines for Aircraft. Ivan H. Driggs and Otis E. Lancaster. New York, The Ronald Press Co., 1955. 349 pp., illus., diagrs. $10.

This book is intended as a reference work for aeronautical and mechanical engineers and all others concerned with the thermodynamics and flow phenomena that determine the performance of gas-turbine power plants in aircraft. It begins with a brief historical survey, then treats in order, basic thermodynamics, engine cycle analysis, the flow of gases (through channels and ducts, and through compressors and turbines), and the combustion process. The authors outline a method for obtaining the complete performance of a gas turbine, starting from the tested parameters of the components. They also give consideration to weight estimation for determining combined engine-fuel weights for various engine designs and flight times. A final chapter reviews the development of the aircraft gas-turbine engine from 1939 to the advent of the ducted fan and the turboprop engine. Problems, tables, charts, and index complete the volume. At the time of his death, Dr. Driggs was Chief Scientist, U.S. Naval Air Development Center. His colleague is Assistant Director of the Research Division of the Bureau of Aeronautics, Department of the Navy.

REFERENCE WORKS

Interavia ABC Directory of World Aviation 1955. 4th Ed. Geneva, Switzerland, and New York, Interavia, S.A., 1955. 1,147 pp. $10.

The first three editions of this comprehensive directory of aviation appeared between the years 1936 and 1939. The present (4th) edition follows the general scheme of the earlier volumes, with the addition of an index to persons in aviation. The size of the volume reflects the vast extension of aviation since the beginning of World War II, even though the data on ten countries of Europe and Asia were not made available to the publishers. The contents are in general correct as of June 30, 1954.

STRUCTURES

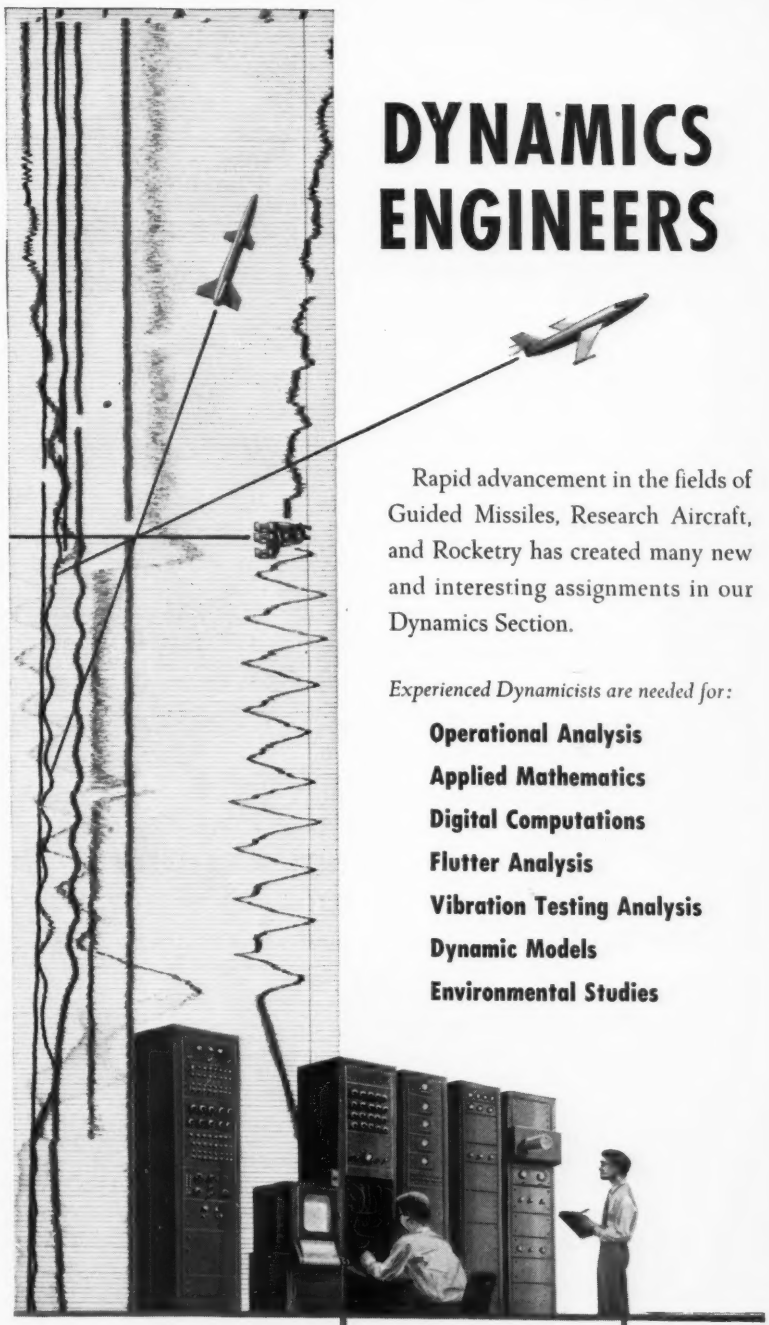
Elements of Structural Engineering. Ernest C. Harris. New York, The Ronald Press Co., 1955. 505 pp., illus., diagrs. $7.00.

A textbook in structural engineering for the noncivil engineering student. The author is Professor and Chairman, Department of Civil Engineering and Engineering Mechanics, Fenn College.

Contents: (1) Introduction. (2) Equilibrium and Reactions. (3) Shear, Thrust, and Bending Moment. (4) Analysis of Trusses and Bracing. (5) Analysis with Moving Loads. (6) Deflections in Beams. (7) Design in Steel—Members. (8) Design in Steel—Connections. (9) Design in Concrete. (10) Design in Timber. Appendix A, Properties and Dimensions of Rolled Steel Sections. Appendix B, Tables. Appendix C, American Welding Society Standard Welding Symbols.

THERMODYNAMICS

Combustion Researches and Reviews 1955; Invited Papers Presented at the 6th and 7th AGARD Combustion Panel Meetings held respectively in Scheveningen, The Netherlands,



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May, 1954 and in Paris, France, November, 1954. (AGARDograph No. 9.) London, Published for and on behalf of AGARD, NATO, by Butterworths Scientific Publications; New York, Interscience Publishers, Inc., 1955. 187 pp., illus., diagrs. $5.00.

This book is an outgrowth of the activities of the AGARD Combustion Panel following upon their Cambridge Colloquium in 1953, a meeting which resulted in an earlier volume entitled, *Selected Combustion Problems*. In addition to the papers listed below it includes a Bilingual List of Technical and Scientific Terms. The Panel intends to publish future volumes under the general title, *Combustion Researches and Reviews*.

Contents: Diffusion Flames in the Laboratory, J. Barr. Some Problems Pertinent to the Combustion of Sprays, M. Gerstein. Some Aspects of Combustion of Liquid Fuel, C. C. Graves and M. Gerstein. La Formation et l'Évolution des Brouillards Combustibles, R. Kling. Some Notes on Spray Combustion, J. R. Joyce. The Correlation of Combustion Efficiency and Injector Characteristics under Simulated Altitude Conditions, Staff of British NGTE. Flame Stabilization and Flame Propagation in Ramjet Combustors, J. P. Longwell. Étude des Limites de Stabilité en Relation avec la Résistance des Obstacles à l'Écoulement, A. Mestre. A Spontaneous Ignition Theory of Combustion Intensity and Combustion Stability Behind a Baffle, B. P. Mullins. The Mechanism of Carbon Formation, G. Porter. Formation et Dépot de Carbone dans les Foyers de Turbomachines d'Aviation, C. Foure. Similarity Analysis for Chemical Reactors and the Scaling of Liquid Fuel Rocket Engines, S. S. Penner. Rayonnement des Flammes et Similitude, C. Codegone. The Role of Wake Transition in the Process of Flame Stabilization on Bluff Bodies, E. E. Zukoski and F. E. Marble.

Introduction to the Study of Chemical Reactions in Flow Systems. S. S. Penner. (AGARDograph No. 7.) London, Published for and on behalf of AGARD, NATO, by Butterworths Scientific Publications; New York, Interscience Publishers, Inc., 1955. 86 pp., diagrs. $3.00.

The author's aim is first, to present an adequate summary of the principles of classical chemical kinetics, which is intelligible to investigators without previous training in chemical kinetics; and second, to provide the necessary basic material for intelligent formulation of flow problems with chemical reactions. The book is divided into four chapters, as follows: I—Classical Chemical Kinetics (Phenomenological Description of Reaction Rates in Stationary, Isothermal Systems). II—Conservation Laws and Transport Coefficients in Reacting Mixtures. III—Chemical Reactions during Adiabatic Expansion Through a De Laval Nozzle. IV—Heterogeneous Chemical Reactions. The author is on the staff of the Guggenheim Jet Propulsion Center, California Institute of Technology.

Spontaneous Ignition of Liquid Fuels. B. P. Mullins. (AGARDograph No. 4.) London, Published for and on behalf of AGARD, NATO, by Butterworths Scientific Publications; New York, Interscience Publishers, Inc., 1955. 117 pp., diagrs. $2.75.

This book is a review and assessment of the state of knowledge in the field of spontaneous ignition of liquid fuels. The author, who is Chairman of the Combustion Panel of AGARD, intends the work also as a sourcebook of the data on spontaneous ignition. After a chapter on general theoretical considerations, the various test methods whereby such data has been obtained are described in successive chapters according to the eight general classifications into which these methods fall. In Chapter Eleven the spontaneous ignition temperatures of liquid substances, determined by many of the methods described earlier, are summarized in alphabetical order. Each entry is keyed to a list of references which makes up the rest of this chapter. The remaining chapters deal with the effect of additives, the factors affecting ignition delay, and applications. A

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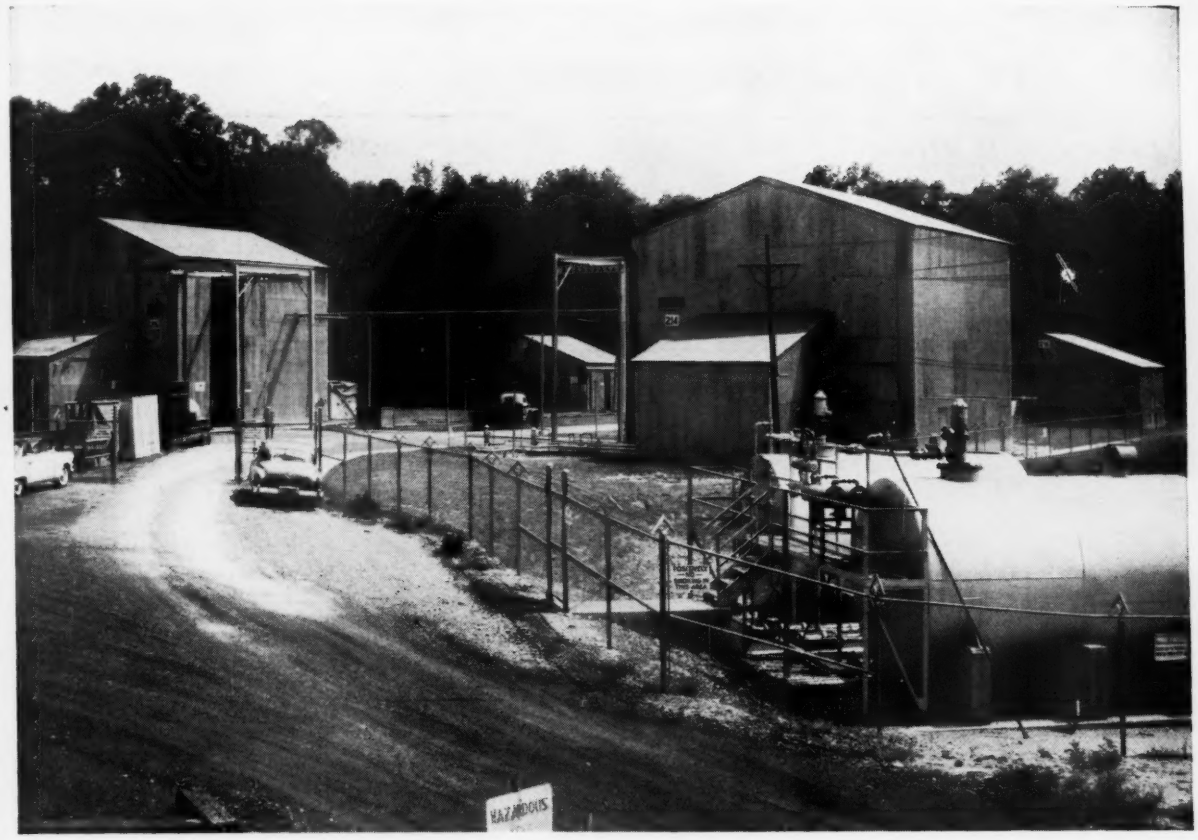

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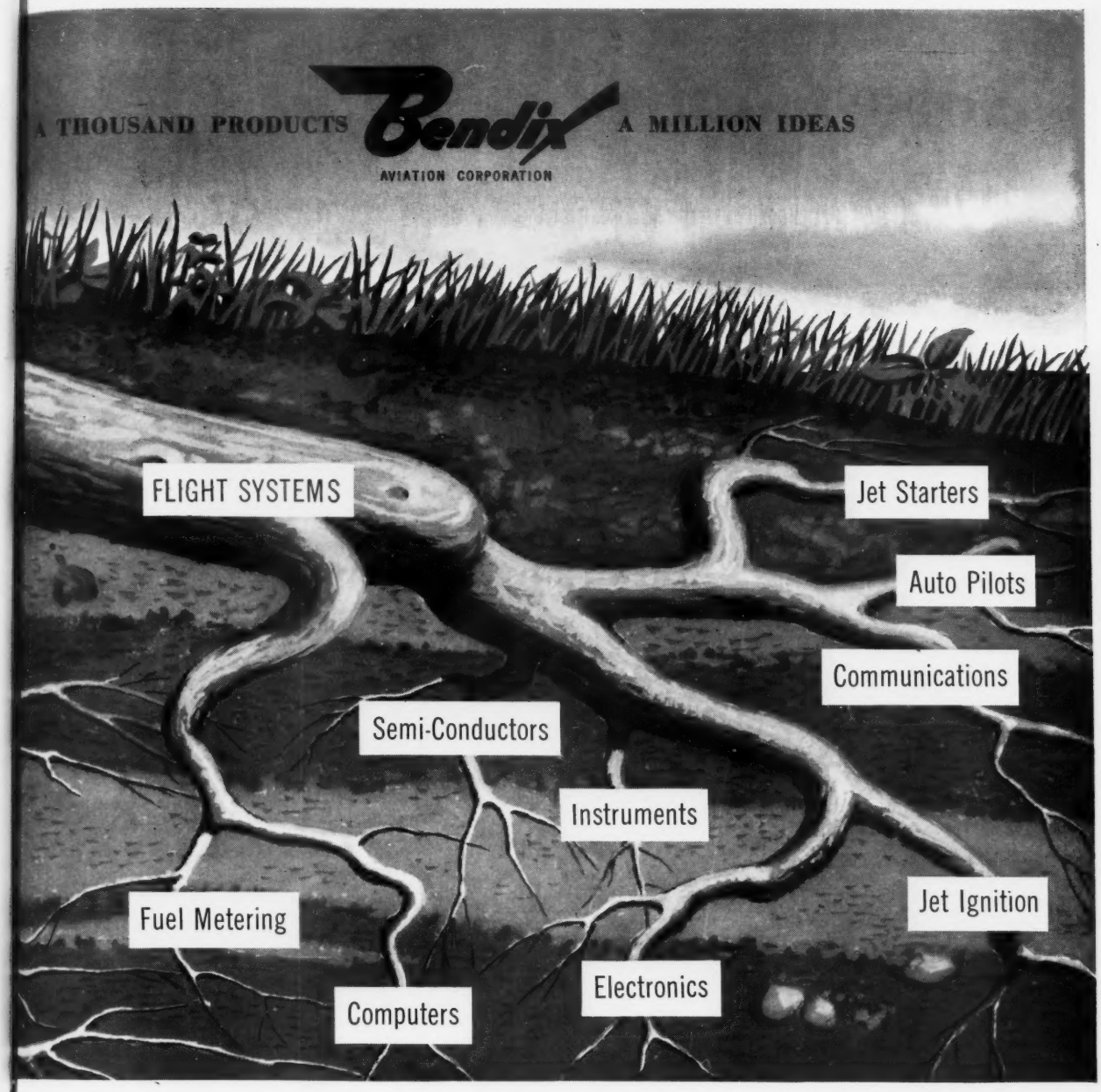

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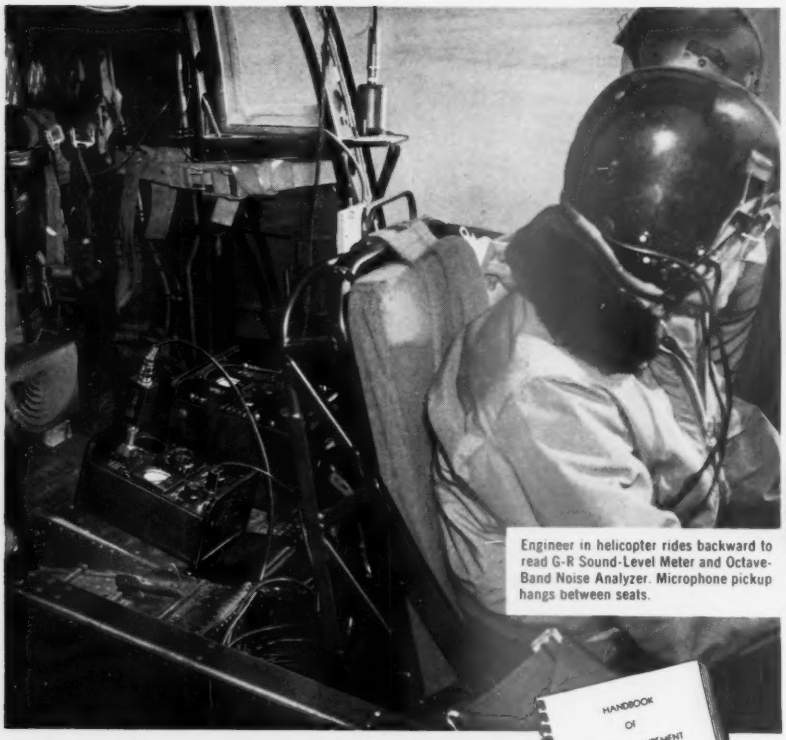

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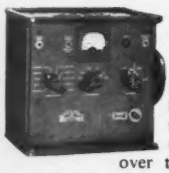

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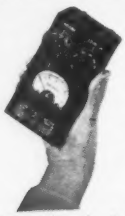

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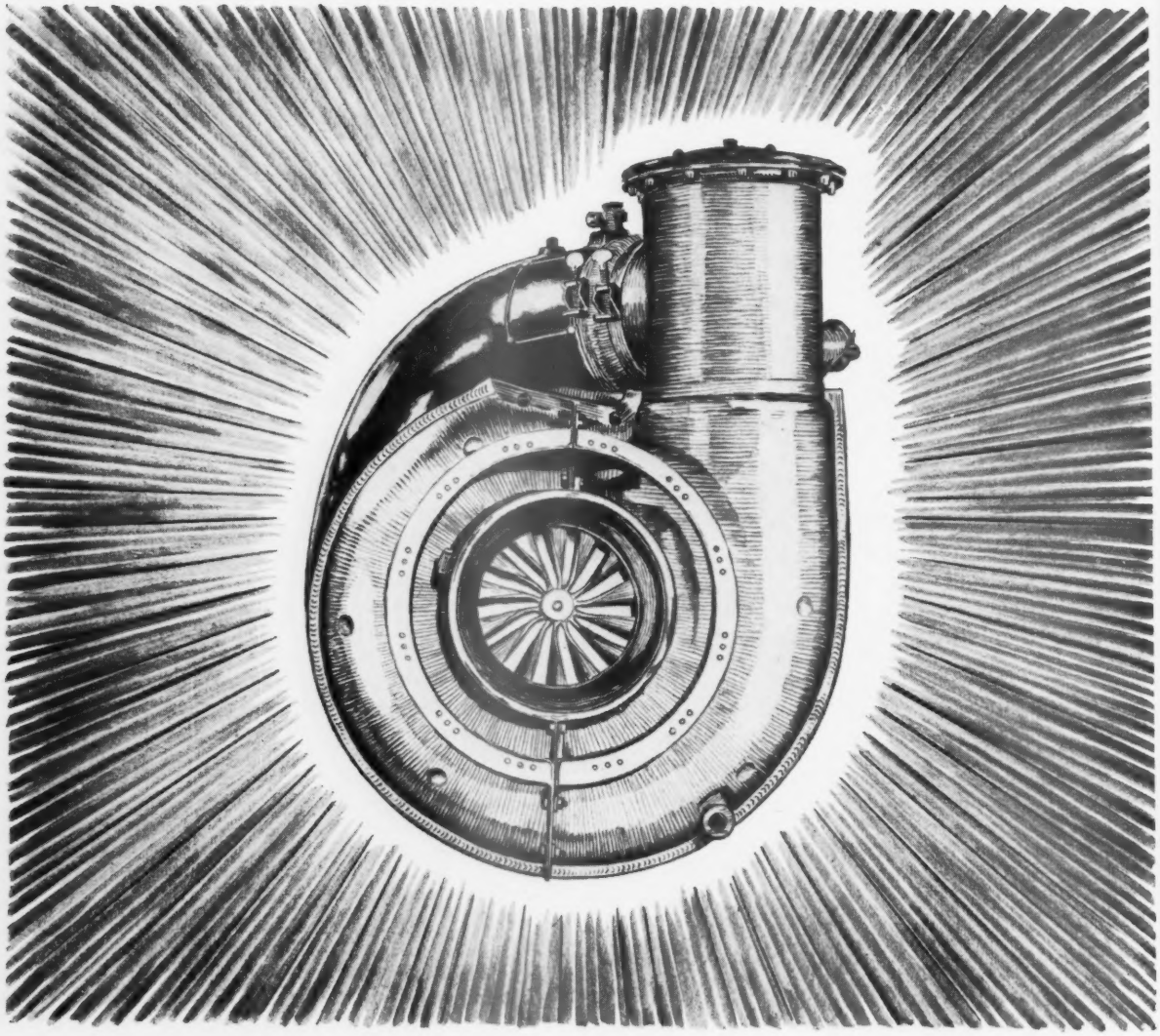

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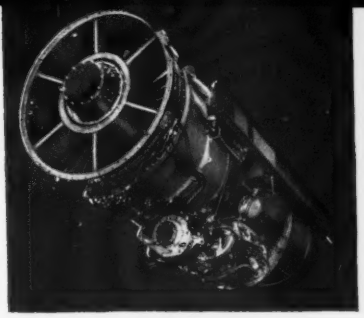

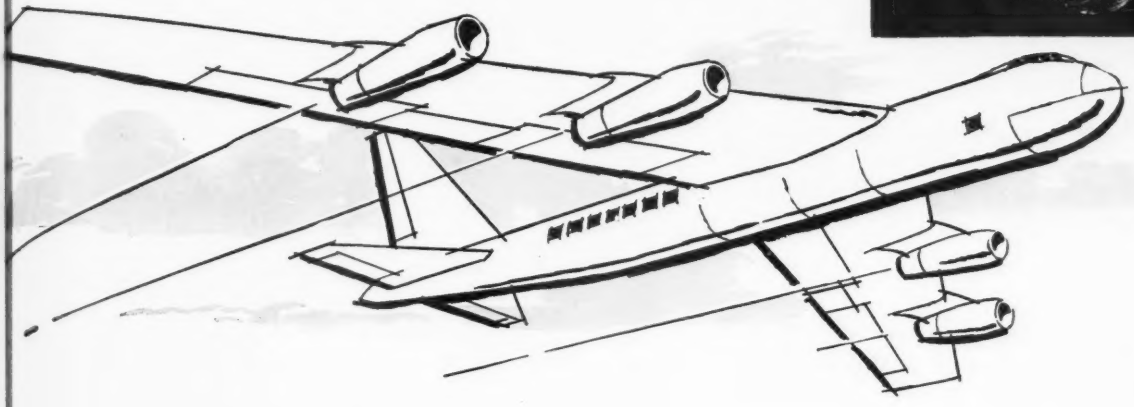

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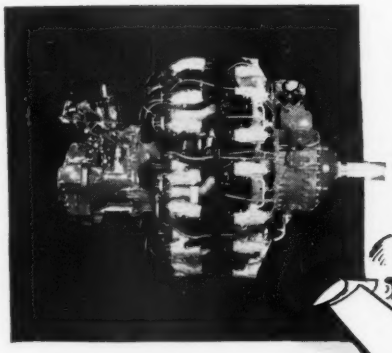

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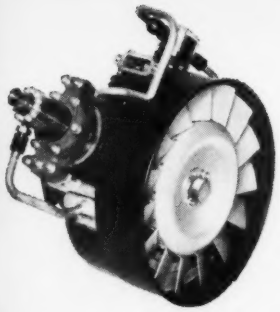

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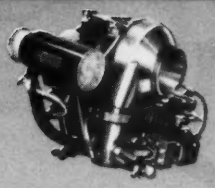

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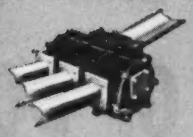

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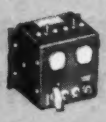
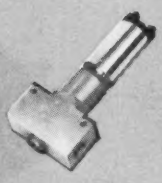
Model TP3 Turbine-Generator Emergency Power Pack

Model 758 Ventilating Fan, Capacity: 900 cfm



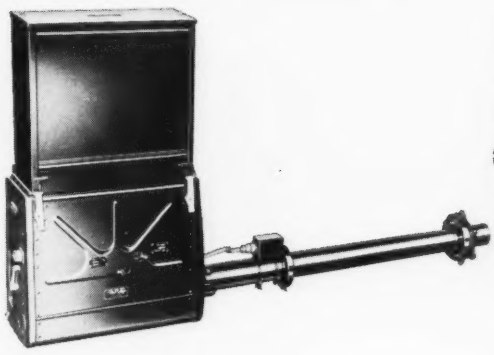
Model 747A Interlock Valve

Model 807 Retro Drift Signal Ejector Control

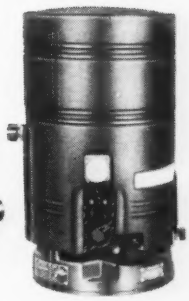


Model 753 SonoBuoy and Flare Release Control

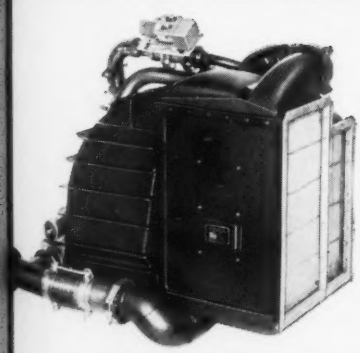
Model 7008 Pneumatic Valve, 3,000 psi, 3-way, 2 position



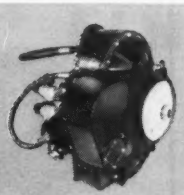
Pneumatic Retro Marine Marker Ejector



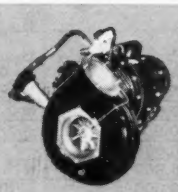
Compressor, 2 cfm, 3,000 psi self-contained, electrically driven



Model EA75 Refrigeration System—Nominal Flow Rating: 75 lbs./min.

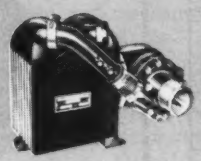


Model S60-11 Cabin Supercharger



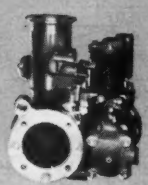
Model S60-5 Cabin Supercharger

Model B60 Bootstrap Refrigeration Unit



Model N15 Air Cycle Machine

Model MS60 Air Moisture Separator



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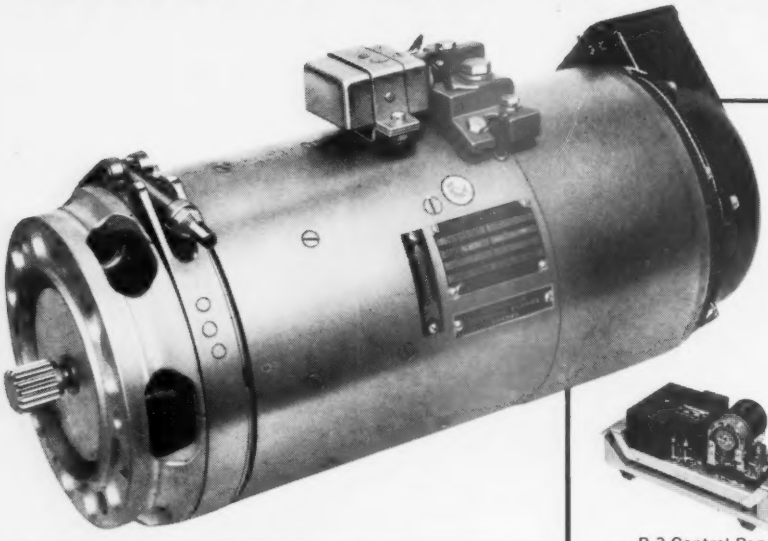
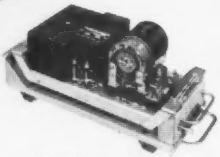
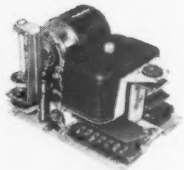


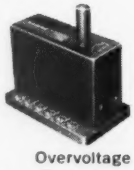
PLUS THIS PROTECTIVE AND CONTROL EQUIPMENT FOR DC SYSTEMS



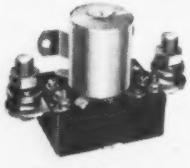
B-3 Control Panel



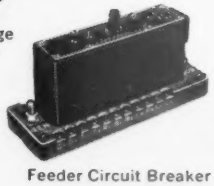
Generator Control Panel



Overvoltage Protector



Line Relay



Feeder Circuit Breaker

Voltage Regulator

Fault Detector Panel

AIRCRAFT-ENGINE-DRIVEN DC GENERATORS FOR 30 VOLT SYSTEMS

Type No.	Nominal Rating			Approx. Weight Lbs.	Designed to Gov't Spec.
	Amps.	Speed Range RPM	Altitude Ft		
30E01	50	2200-4500	20,000	24	M-2, M-3
1345	50	4000-8500	30,000	14.25	
30E22	50	4000-8500	30,000	16.25	
30E14	75	4000-8000	25,000	24.5	N75-2RA
30E16	100	2500-4500	50,000	40	52B6588
30E20	150	4000-8000	65,000	45	
30E17	200	2870-8600	Ground Power	40	
30E07	200	3000-8000	50,000	45	AN-3632
30E18	200	4000-8000	50,000	38	MS-25009
30E19	250-350	1600-7500	Ground Power	98	
30E02	300	3450-8500	25,000	64	
30E15	300	4000-8000	50,000	50	AN-3623
30E05	400	3000-8000	50,000	68	AN-3634
30E10	400	3100-8000	60,000	67	AN-3624
30E11	500	4000-8000	50,000	75	
30E13	500	3500-8000	50,000	86	

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With the touch of a finger...

sea level comfort for The Golden Falcon

Aboard Eastern Airlines new DC-7B Golden Falcons the flight engineer can create maximum pressurized comfort with a touch of a finger. A new AiResearch cabin pressure control system makes this possible.

Working with Douglas engineers, AiResearch designed a pneumatic butterfly outflow valve for the Eastern DC-7B fleet. The outflow valve was developed for a ducted installation and is connected by a small air line to a lightweight AiResearch controller located at the flight station. The new valve permits cabin pressure to be *its own source of power* — the basic pneumatic principal of all AiResearch pressurization systems.

Eastern Airlines reports that the new system has already passed the 1000 hour mark of trouble free operation and that passenger reaction has been most favorable. Dependability, compactness and easy maintenance are other features which made this integrated system a must for Eastern's new DC-7B's. In the field of integrated aircraft systems and specialized components AiResearch has more experience than any other company.

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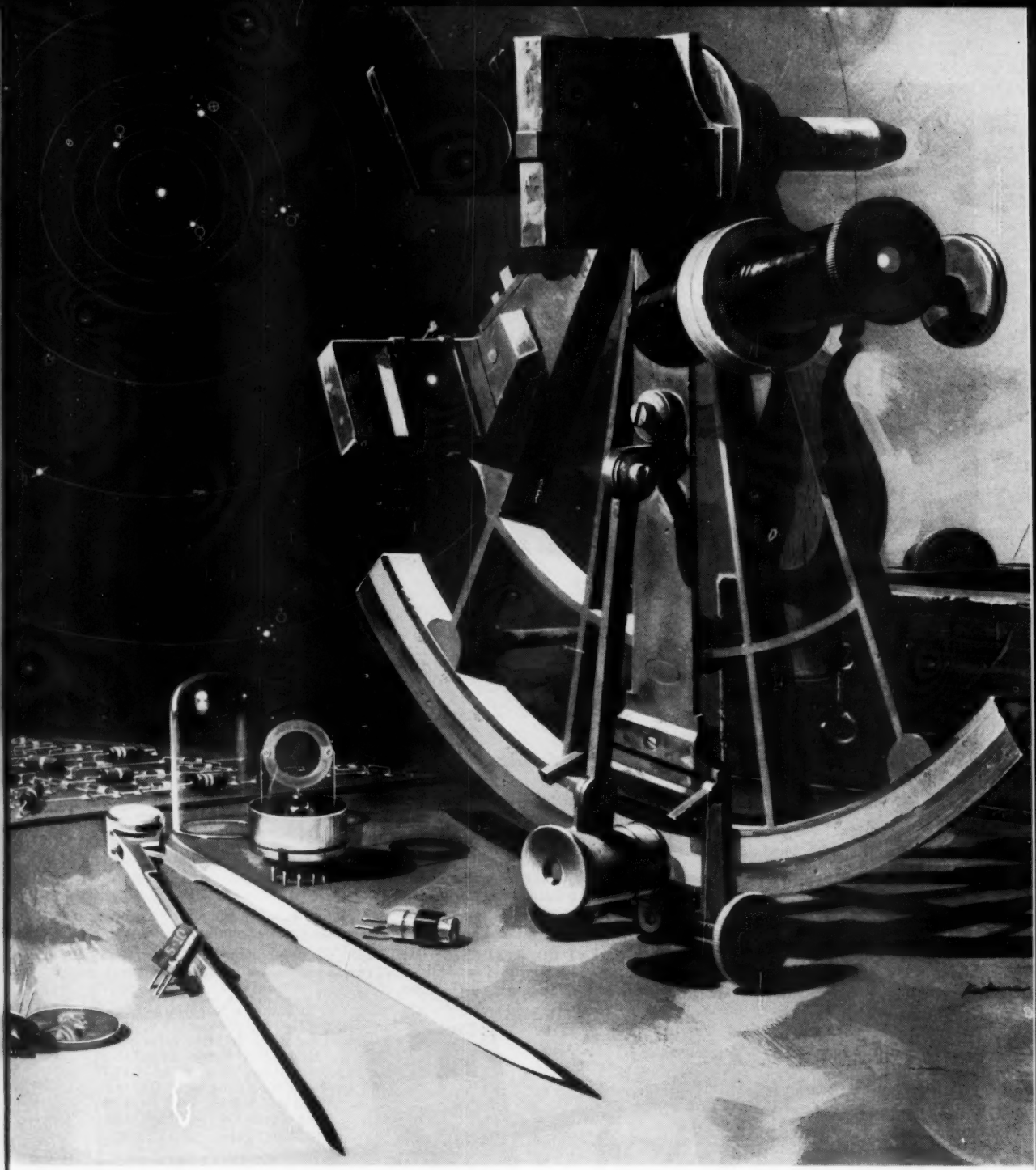

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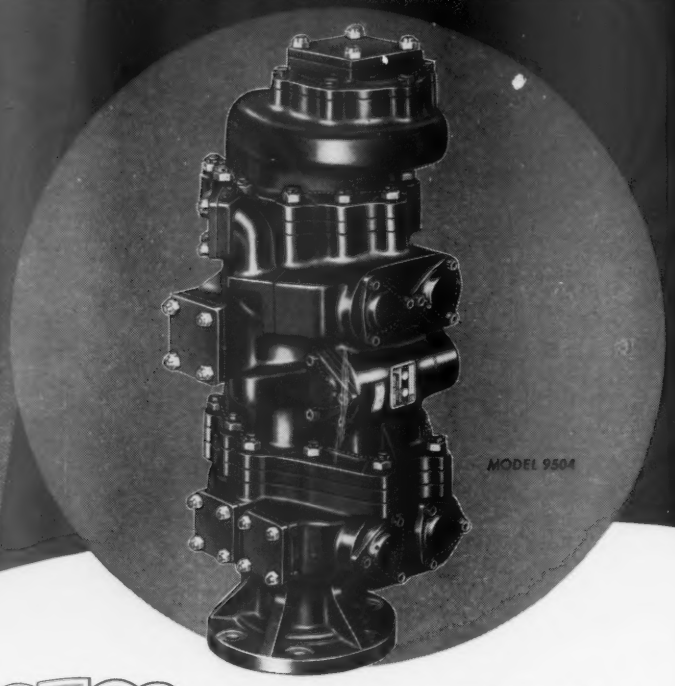
54-45

There IS a BIG difference in fuel pumps



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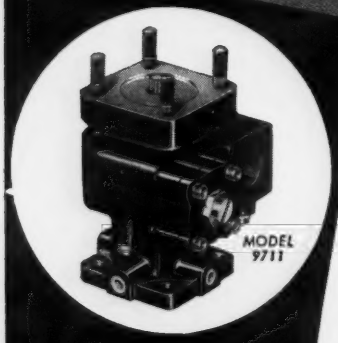
ALIGNMENT CONSTRUCTION METHOD . . . Components are centered in a common bore, easier to disassemble and reassemble for routine maintenance; no complicated re-alignment is required.

If a bonus in performance can help your present projects, send for more detailed information about CECO Pumps . . . and about completely integrated CECO Fuel Pumping and Control Systems. Ask for your copy of "Engineered For The High And The Mighty . . ."



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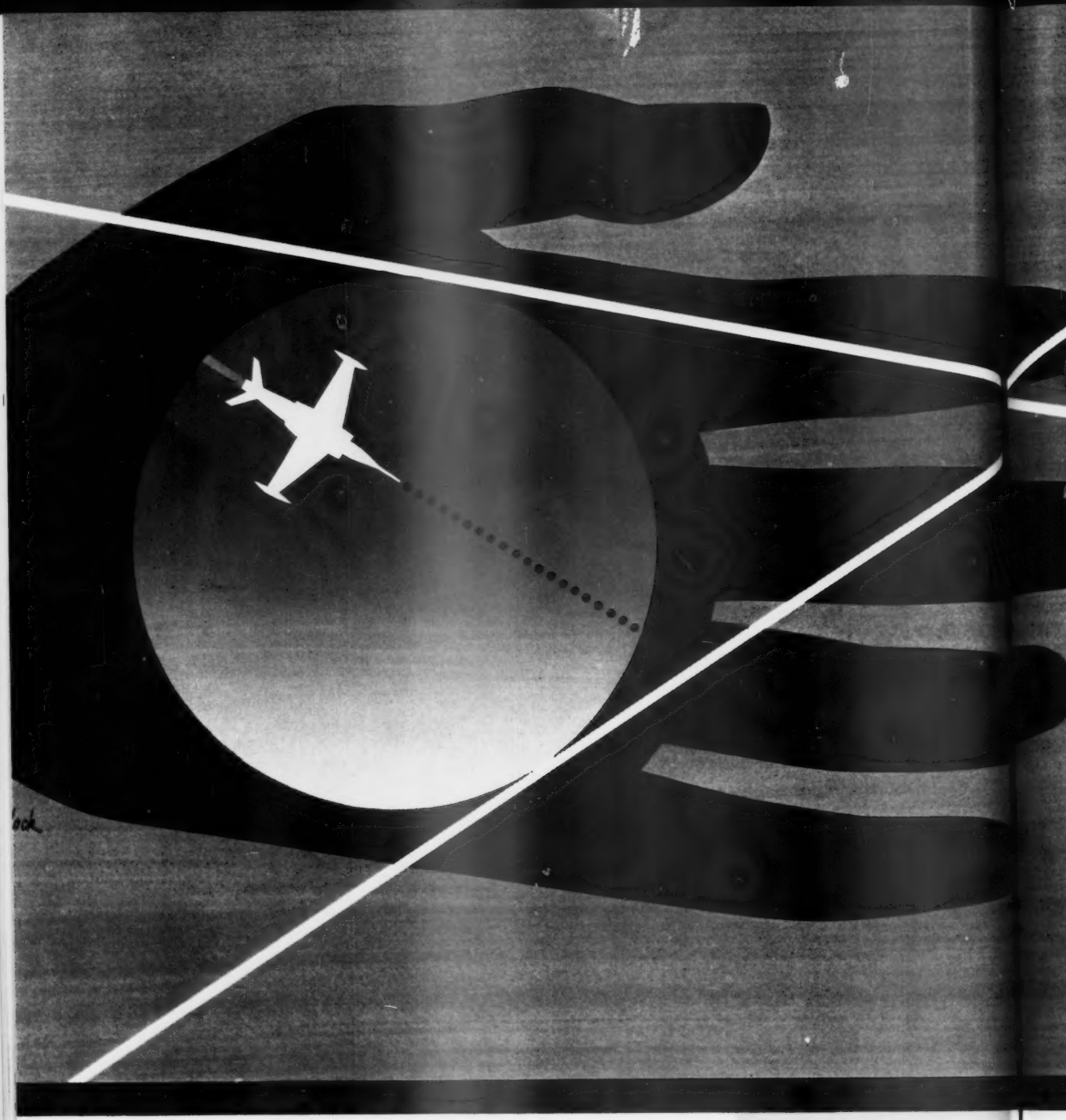

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From Crosley— new dimensions for the electronic age

As electronics works its magic for defense and industry, scientists of Avco's Crosley Division reckon with the problem of making already reliable electronic systems more flexible—to give them greater usefulness in navigation, communication, national defense. Now, out of intensive study of electronics and related areas—thermodynamics, optics, aerodynamics, human factors—has emerged the knowledge necessary to achieve this critical goal. Working closely with the military, outstanding Crosley scientists have changed the dimensions of many electronic systems: lightening them, compressing them, "miniaturizing" them. Now—improved radar, communications receivers, navigational aids, and scores of other systems are coming off the Crosley lines and performing their miracles in smaller space, with less weight, requiring less power. Through "miniaturization" in electronics, as well as advances in air-frame assemblies, Crosley brings the findings of research to practical fulfillment—for defense, for peace.

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for Fairchild small jet engine

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*Fluoroflex is a Resistoflex registered trade mark for products from fluorocarbon resins. Teflon is the DuPont registered trade mark for its tetrafluoroethylene resin.

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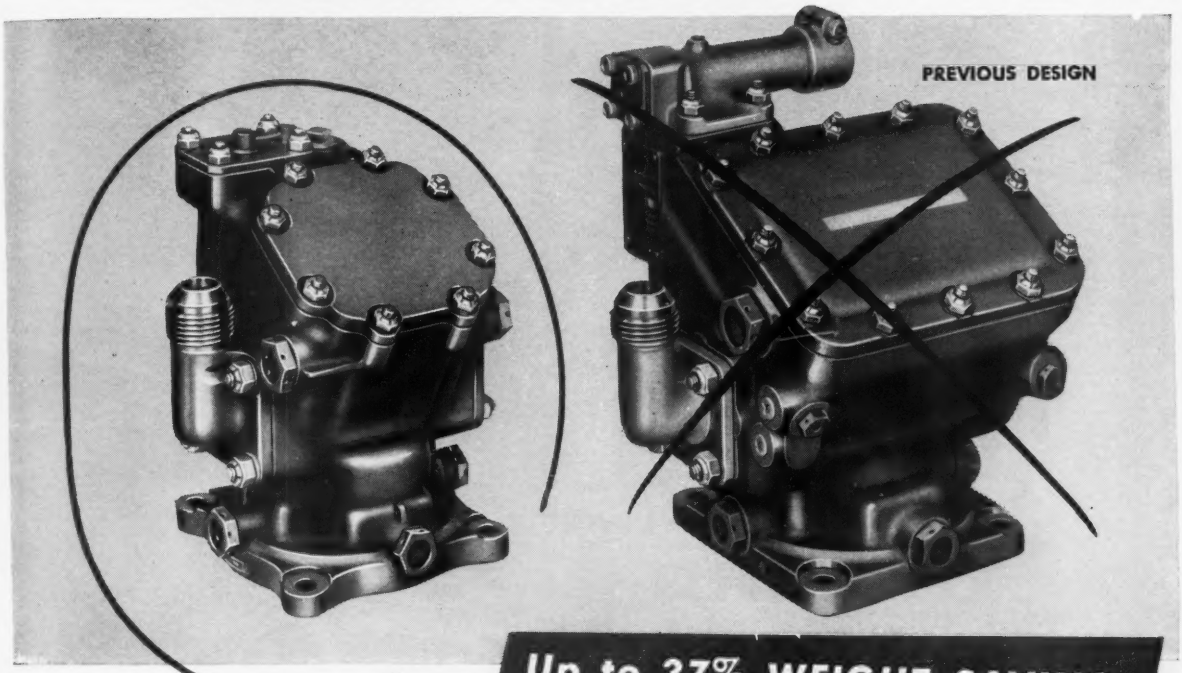

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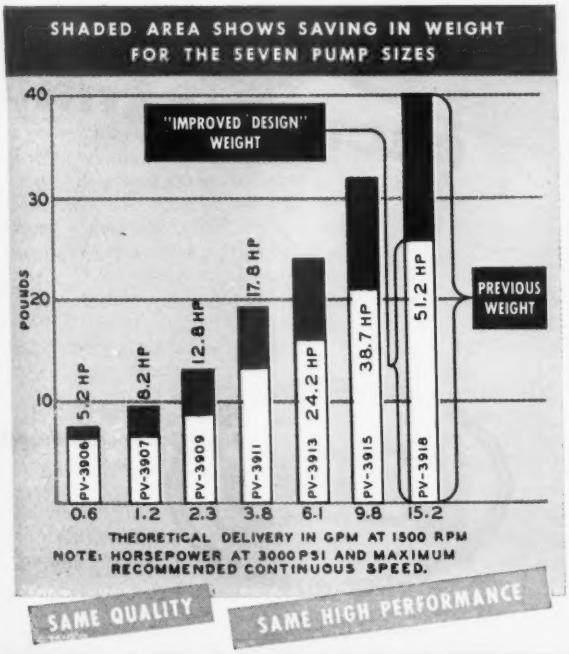

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Boeing "Aeros" help create America's first jet transport

Here is another important "first" for Boeing aeronautical engineers. It is the Boeing Jet Stratoliner 707, shown here as it will look when it takes to the air. Many Boeing aeronautical engineers are now at work perfecting this epochal airliner. Other aeronautical engineers are developing the years-ahead airplanes and guided missiles that will continue to enhance Boeing leadership—and their own professional prestige.

A prototype of the 707 has been flight-tested for well over a year, both as a commercial jet transport and as the KC-135 jet tanker for the Air Force. Boeing engineers are proud of their vital contributions to this and other aircraft: the Boeing IM-99 Bomarc pilotless interceptor, now under intensive development . . . the giant B-52 global bomber, at present being delivered to units of the Air Force . . . the B-47 jet bomber, mainstay of Strategic Air Command. These engineers are members of aviation's top creative team. There are more than twice as many of them with Boeing now than at the peak of World War II. This is evidence of the company's solid expansion, and of the opportunities for engineers' career growth.

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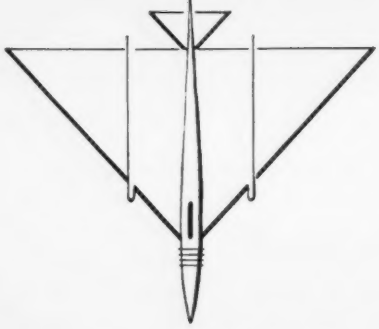

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Growing importance of missiles in the nation's defense has led to the separation of missiles engineering from aircraft engineering functions at Douglas Aircraft Company.

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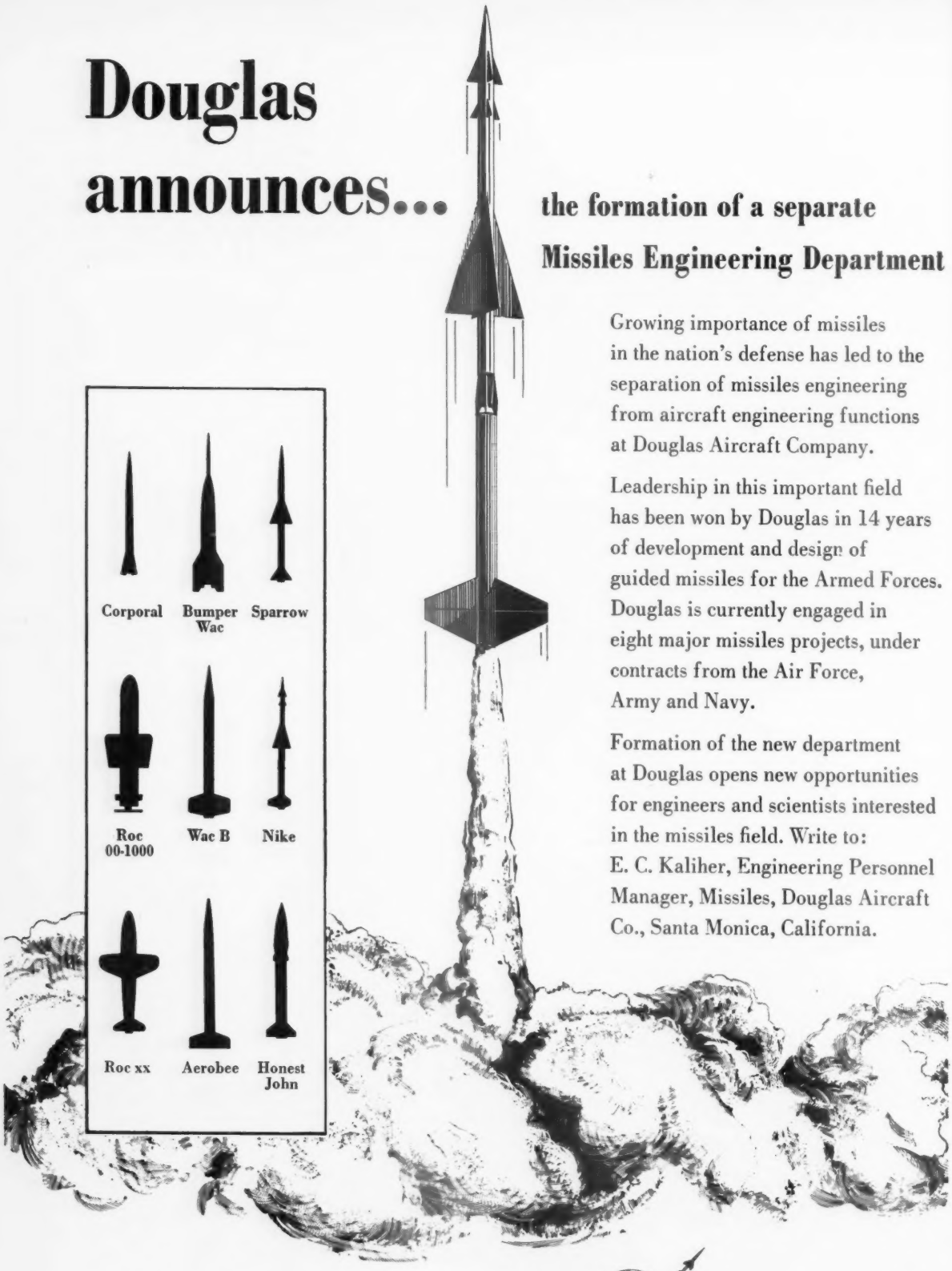
Formation of the new department at Douglas opens new opportunities for engineers and scientists interested in the missiles field. Write to: E. C. Kaliher, Engineering Personnel Manager, Missiles, Douglas Aircraft Co., Santa Monica, California.



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Personnel Opportunities

This section is for the use of individual members of the Institute seeking new connections and organizations offering employment to Aeronautical specialists. Any member or organization may have requirements listed without charge by writing to the Secretary of the Institute.

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Manager of Engineering—East Coast aircraft equipment manufacturer offers unusual opportunity for top caliber engineer to head a fast moving, growing engineering staff engaged in many long-range development programs. The man for this position should have heavy experience in aircraft fuel system design with some hydraulic experience desirable. He should have administrative experience particularly in engineering scheduling and budgetary control; tact and personality to assist Sales Department in "high level" technical selling. This is one of top five positions in this aggressive, well-backed firm with a new plant employing 400 and operating in one of the most rapidly expanding fields of aviation development. All normal executive benefits provided plus moving expenses. Salary open. Our personnel are aware of this ad. Address all inquiries (in strictest confidence) with résumé to Suite 1403, 52 Vanderbilt Avenue, New York 17, N. Y.

Aeronautical Engineer—Princeton University has an opening for an engineer experienced in airplane dynamic stability and control. A graduate degree is preferred. Position is for Project Engineer on pilot response flight-test program. Please send résumé to: Edward Seckel, Professor, Aeronautical Engineering, James Forrestal Research Center, Princeton University, Princeton, N.J.

Engineers—Fairchild Engine Division of the Fairchild Engine and Airplane Corporation, Deer Park, Long Island, N.Y. Diversified engineering positions are available involving engine research, design, design and performance analysis, test engineering, compressor and turbine design, control systems, and other engineering operations associated with the general field of design and development of gas turbine power plants. These opportunities result from expanded programs in a new plant and gas turbine laboratory. Send résumé to: Felix Gardner, Fairchild Engine Division, Deer Park, Long Island, N.Y.

Engineers—Growing research and development organization has need for engineers experienced in supersonic and hypersonic fluid mechanics, supersonic wing theory, missile dynamic and control analysis, missile trajectory and dispersion analysis, aerodynamic heating, heat conduction, ballistic-range or free-flight research techniques, and basic research in fluid mechanics. Openings also exist for structural, aerothermo, and research engineers. Send résumé to: Frances Hill, Personnel Manager, Aerophysics Development Corporation, P.O. Box 949, Santa Monica, Calif.

Engineers—Bendix Products Division at South Bend, Ind., pioneer and leader in the design, development, and production of commercial and military aircraft components and automotive devices, has continuing opportunity in a variety of assignments on interesting long-range projects. Engineers are needed in this organization which has a growth tradition, who have 2 to 5 years of experience in propulsion systems, thermodynamics, shock and stress, servomechanisms, dynamics, fluid mechanics, analogue and digital computers, fuel control systems for aircraft and automotive engines, aerodynamics, mechanical test equipment, and liquid propellants. Many other engineering opportunities are immediately available for Mechanical, Electrical, and Aeronautical Engineers. Please send résumé outlining education, experience, and salary level to Technical Placement, Employment Department, Bendix Products Division, Bendix Aviation Corporation, South Bend 20, Ind.

The number preceding the notice represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

Engineers, Electronic Scientists, Metallurgists, Physicists, Physiologists, Psychologists, Technologists—The Naval Air Material Center, located at the Naval Base, Philadelphia, Pa., has vacancies in the above engineering and scientific positions which must be filled. The Center is engaged in an extensive program of aeronautical research, development, experimentation and test operations for the advancement of Naval Aviation. Engineering vacancies exist in the following options: Electrical, Electronics, General, Industrial, Mechanical, Structural, and Aeronautical (various suboptions). Starting salaries range from $3,670 to $8,990 per annum. Application for Federal Employment, Standard Form 57 should be filed with the Industrial Relations Department, Naval Air Material Center, Naval Base, Philadelphia 12, Pa. Applications may be obtained from the above address or information as to where they are available may be obtained from any first or second class Post Office.

Engineers—Gas Turbine Engineers—Solar Aircraft Company in San Diego, California has several immediate openings for qualified engineers which represent outstanding career opportunities. The firm has been designing, developing, and producing small gas-turbine engines for several years, and recently has received additional contracts—both for new development and production—which make necessary considerable expansion of the engineering staff. Concurrent with the expansion of personnel, construction has just been completed of a new Engineering Office Building and a new Engineering Test Laboratory, on the firm's leasehold alongside San Diego Bay. Solar needs **Mechanical Design Engineers** for laying out new gas-turbine engine configurations, **Experimental Engineers** for directing development test programs, and **Electromechanical Design Engineers** for work in air-borne controls devices and systems. These are responsible positions, with opportunity for rapid advancement into openings for **Project Engineers.** B.S.M.E. or A.E. preferred, with 3 or more years' experience. Liberal relocation allowances. Inquiries will be held confidential. Write, giving résumé of experience to: P. M. Klauber, Chief Administrative Engineer, Solar Aircraft Company, San Diego 12, Calif.

Aircraft Structural Engineer—Annual salary of $7,570. Position involves conducting strength evaluations in civil aircraft and the preparation of technical instructions and information covering air-frame structural design criteria. Bachelor's degree plus 3½ years' of progressive professional experience required. Lacking degree, equivalent combination of education and experience permitted. **Flight Test Engineer**—Annual salary of $7,570. Position involves studies and preparation of engineering flight-test and flight analysis procedures and methods relative to performance and quantitative measurements of operating and flight characteristics of aircraft. Bachelor's degree in aeronautical engineering plus 3½ years of progressive professional experience required. Lacking degree, equivalent combination of education and experience permitted. Applicants should submit Standard Form 57, Application for Federal Employment (available at any Post Office) to: Personnel Office, W-91, Civil Aeronautics Administration, 16th and Constitution Avenue, N.W., Washington, D.C.

Engineers—The Civil Aeronautics Administration urgently needs Aeronautical Engineers to conduct tests and studies to determine the dynamic effects of crash loads on aircraft fuel tanks and supporting structure, and engineers to conduct development projects in the field of aircraft power plants. Salaries range from $4,345 to $7,570 per annum. Inquiries or application on Standard Form 57, which can be obtained at your Post Office, should be directed to Personnel Officer, Civil Aeronautics Administration, Technical Development and Evaluation Center, P.O. Box 5767, Indianapolis, Ind.

Engineers—The following vacancies exist at the Special Devices Center, Port Washington, New York. **Aeronautical Engineer**—$4,345 per annum (Requirement: B.A.E. degree). **Aeronautical Engineer**—$4,930 per annum (Requirement: B.A.E. degree plus 6 months' professional research and development experience). **Aeronautical Engineer**—$5,440 per annum (Requirement: B.A.E. degree plus 1½ years' professional research and development experience). **Aeronautical Engineer**—$6,390 per annum (Requirement: B.A.E. degree plus 2½ years' professional research and development experience). Inquiries should be addressed to the Commanding Officer and Director (Attention: Industrial Relations Officer), Office of Naval Research, Special Devices Center, Port Washington, Long Island, New York. Telephones: FLushing 7-8300 or Port Washington 7-3800.

Engineers—Aeronautical Engineers—The Navy Department, Bureau of Aeronautics, has a number of positions available in the following fields of aeronautical engineering including research and development: structural loads, vibration and flutter, aerodynamic heating, cruise control, performance, and related mechanical, electrical, and electronic components. Salaries for most positions are at the GS-11, $6,390 per annum and GS-12, $7,570 per annum levels. Positions require 2½ or 3½ years of experience. Applications, Standard Form 57 (available at most Government offices), should be sent to: Bureau of Aeronautics, Personnel Division (PE-202), Main Navy Building, Washington 25, D.C. **Aeronautical Development Engineer**—This position is also available with the Bureau of Aeronautics, at the GS-14 salary level, $10,320 to $11,395 per annum. The incumbent will be responsible for directing the work of a branch which will include the following functions: (a) planning and administering research and development programs related to special weapons effects, (b) coordinating Bureau of Aeronautics participation in atomic weapon tests, (c) developing design criteria and establishing specification requirements to insure suitability of new aircraft for delivery of special weapons, and (d) preparation and promulgation

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of weapon effects handbook material to the fleet. Required qualifications include a comprehensive background in aircraft structures and aerodynamics, some knowledge of operational tacts and nuclear blast effects, and the ability to design test programs. Applications should be sent to the above address.

Associate Professor or Professor—The School of Engineering of the University of Wichita has a vacancy in the rank of Professor or Associate Professor of Aeronautical Engineering to instruct senior and graduate courses in the fields of stress analysis and structural dynamics. If desired, an abbreviated teaching load may be combined with research conducted in the Department of Engineering Research. Appointment will be for 11 months each year with a salary dependent on experience. Applicant should have Ph.D. degree. Apply: Head, Department of Aeronautical Engineering, University of Wichita, Wichita, Kan.

Engineers—Princeton University, Department of Aeronautical Engineering, Jet Propulsion Research Program has positions available for qualified engineers, as described below, for work on basic and engineering researches in the field of jet propulsion. These are key positions in the Jet Propulsion Research Program of the Department of Aeronautical Engineering, located at the James Forrestal Research Center. Opportunity is provided for responsible research in jet propulsion and associated sciences. These positions are academic appointments with corresponding university privileges, including 1 month annual vacation, participation in graduate course work, and other benefits. **Senior Research Engineer**—Recent Ph.D. in any of the sciences relating to combustion or M.S. with several years' experience to serve as engineer in charge of research projects. **Instrumentation Engineer**—M.S. with several years' experience or equivalent to head staff instrumenting group. **Junior Research Engineer**—Research-minded M.S. or B.S. with experience in rocket system technology and/or propellant evaluation and background in chemistry to serve as assistant engineer in charge of a research project. Please send résumé or request for further information to: Mr. J. P. Layton, Chief Jet Propulsion Research Engineer, Department of Aeronautical Engineering, James Forrestal Research Center, Princeton University, Princeton, N.J.

Engineers—Openings for Layout and Design Engineers, Draftsmen, Aerodynamicists, Stress Analysts, Weight Analysts, Loftsmen, Service Engineers. Excellent opportunities in a progressive organization, involving design, engineering, and production of new concepts in aircraft. Please address résumé of your qualifications to: Mr. R. C. Ward, Director of Personnel, Stroukoff Aircraft Corporation, West Trenton, N.J. Telephone: EXport 6-7551.

708. Engineering Analyst—Young man with Bachelor's degree in Engineering and/or in Business Administration with 4 to 6 years' experience closely related to development of a highly technical product. Must be capable of taking initiative and have a lively imagination regarding the presentation of analytical information. Will be expected to work with Engineering Management in formulating programs and objectives and in monitoring progress. Work will require being in touch with research, design, manufacturing, testing, financial, and marketing phases of turbojet engine projects. Please submit résumé including education and experience.

Available

707. Engineering Executive—Registered professional engineer; under 40; consultant, former vice-president—engineering and sales in pilotless aircraft field; considerable design, testing, teaching, and Government contact background. Author of numerous classified proposals, reports, and studies. Washington representative. Listed in *Who's Who*. Seeks joint effort promotional and design proposition on long-term responsible affiliation with aggressive organization active in

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MECHANICAL DESIGN CONSULTANT—Direct the mechanical design activities of weapons systems and radar.

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PROJECT LEADER FIRE CONTROL—Technically direct a major Radar Fire Control project.

ENGINEER—SERVO MECHANISMS—Analyze transient of loop response; develop position control and hydraulic servos.

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706. Representative-Executive—B.A. and M.B.A. degrees; 14 years' aircraft experience (sales, service, and production) Government buyer aircraft equipment. Field and factory representative. Automotive staff experience. Desires association with aviation division of commercial equipment firm. Midwest or Southwest preferred. Opportunity important. Brochure available.

705. Aeromechanical Engineer—B.M.E. Age 37. Fourteen years' engineering experience in the aircraft industry. Last 5 years in planning, organizing, and directing guided-missile electromechanical systems development and engineering programs. Seven years in flight-test research. Two years in stress analysis. Currently engaged in divisional planning of guided-missile flight control systems programs. Desires technical administration position in missile, aircraft, or allied fields. Minimum salary requirement is $11,000 per year. Résumé furnished on request.

Reviews

(*Continued from page 102*)

Wind Tunnels & Research Facilities

Experimentelle Untersuchung der kompressiblen Strömung an und in der Nähe einer gewölbten Wand. W. Frössel. *Max-Planck-Inst. für Strömungsforschung, Mitteil.*, No. 4, 1951. 105 pp. 13 refs. In German. Experimental investigation of high-speed compressible flow conditions on and near an arched wind-tunnel wall, with pressure measurements using Töpler's schlieren technique.

Der Rohrwindkanal. Hubert Ludwieg. *ZFW*, July, 1955, pp. 206–216. In German. Investigation of wind-tunnel design criteria and methods to improve operational characteristics in terms of Reynolds and Mach Number increases, testing techniques, and other requirements.

La Visualisation au Service de l'Aéronautique. R. Outurquin. *Tech. et Sci. Aéronautiques*, No. 3, 1955, pp. 179–184. In French. Evaluation of the SFECMAS visualization techniques applied to supersonic aerodynamic research using detailed photographic recordings of nonsteady flows and motions for varying degrees of instability.

Ersatz für Windkanalmessungen bei besonderer Berücksichtigung von Messungen im freien Fluge. Wilhelm Neuberger. *ZFW*, July, 1955, pp. 216–235. 32 refs. In German. Testing techniques based on an indirect determination of aerodynamic forces from the motion of a rigid body of arbitrary shape in free air to supplement use of costly wind tunnels.

Modell-Messverfahren der Flugtechnik. Rudolf Schmidt and Paul Klages. *ZFW*, July, 1955, pp. 169–205. 62 refs. In German. Analysis of model testing techniques in terms of reliability and similarity law requirements and sources of disturbance and error, with a description of wind-tunnel apparatus, and with an extensive review of the literature.

Rocket Powered Test Vehicles. D. L. Arenson, J. H. McClow, Jr., and H. W. Wiant. *Jet Propulsion*, Sept., 1955, Part I, pp. 441–445, 466, 467. Design and performance of the test vehicles used at the Edwards AFB Free Air Facility Track to study such problems as ejection-seat and recovery-parachute operations at supersonic speeds.

Books

(*Continued from page 110*)

bibliography of 347 references is included, as well as separate author and subject indexes.

Some Fundamentals of Combustion. D. B. Spalding. (Gas Turbine Series, Vol. 2.) London, Butterworths Scientific Publications; New York, Academic Press Inc., 1955. 250 pp., illus., diagrs. $7.50.

This book is written for engineers and others who are concerned with the design of combustion equipment. It emphasizes the physical processes of mixing between fuel and oxygen and between burned and unburned gases, and also the chemical processes that limit the possible rates of reaction. Chapters are included on pertinent aspects of thermodynamics, fluid flow, and heat and mass transfer. Since the problems treated are common to all steady flow combustion equipment, the relevance of the book is not limited to the gas turbine. An extensive bibliography, as well as an index are provided. The author, formerly of the Engineering Department of Cambridge University, has published a number of papers recently on fuel and combustion.

Thermodynamics. Ray L. Sweigert and Mario J. Goglia. New York, The Ronald Press Co., 1955. 355 pp., diagrs., figs. $6.50.

The authors, who are, respectively, Dean of the Graduate Division and Professor of Mechanical Engineering, at Georgia Institute of Technology, have written specifically for the engineering student in his junior year at college. The text presupposes courses in college physics, calculus, and, to a certain extent, differential equations. Being a textbook, few data have been included on the thermodynamic properties of materials. Emphasis throughout has been placed upon an arrangement of material best suited to aid and stimulate the student.

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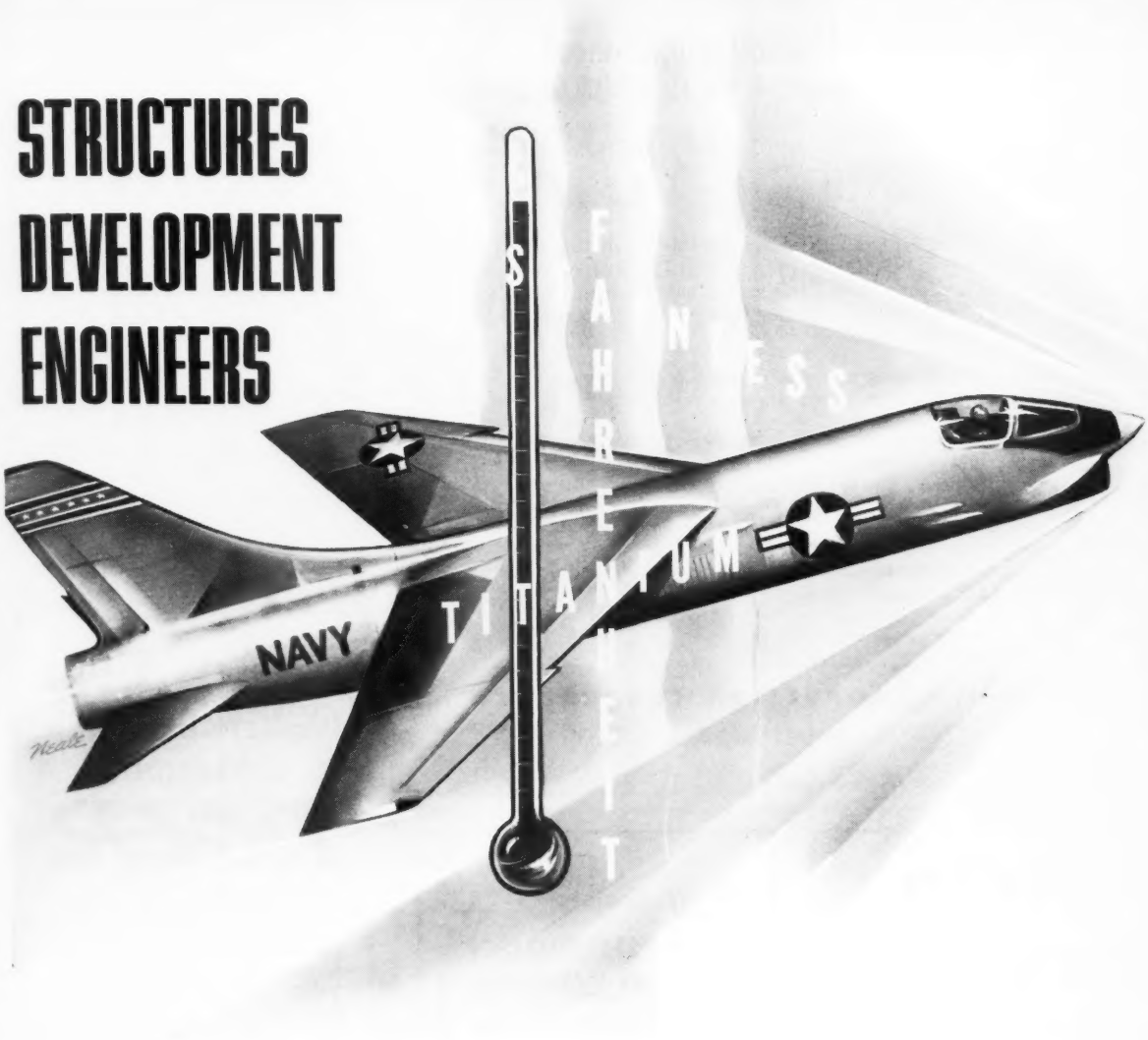

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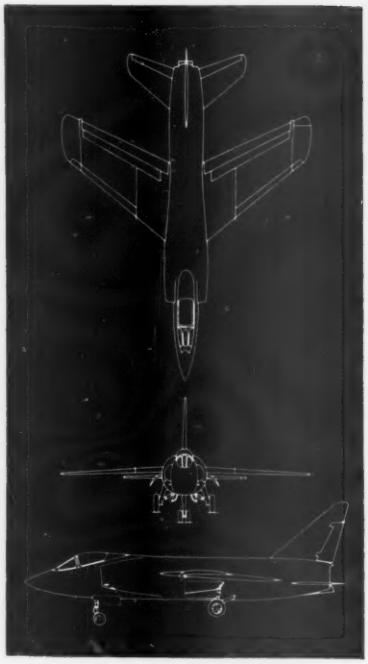

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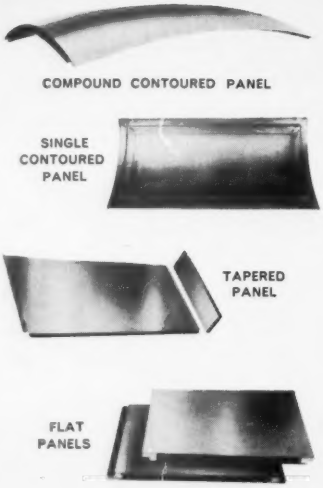

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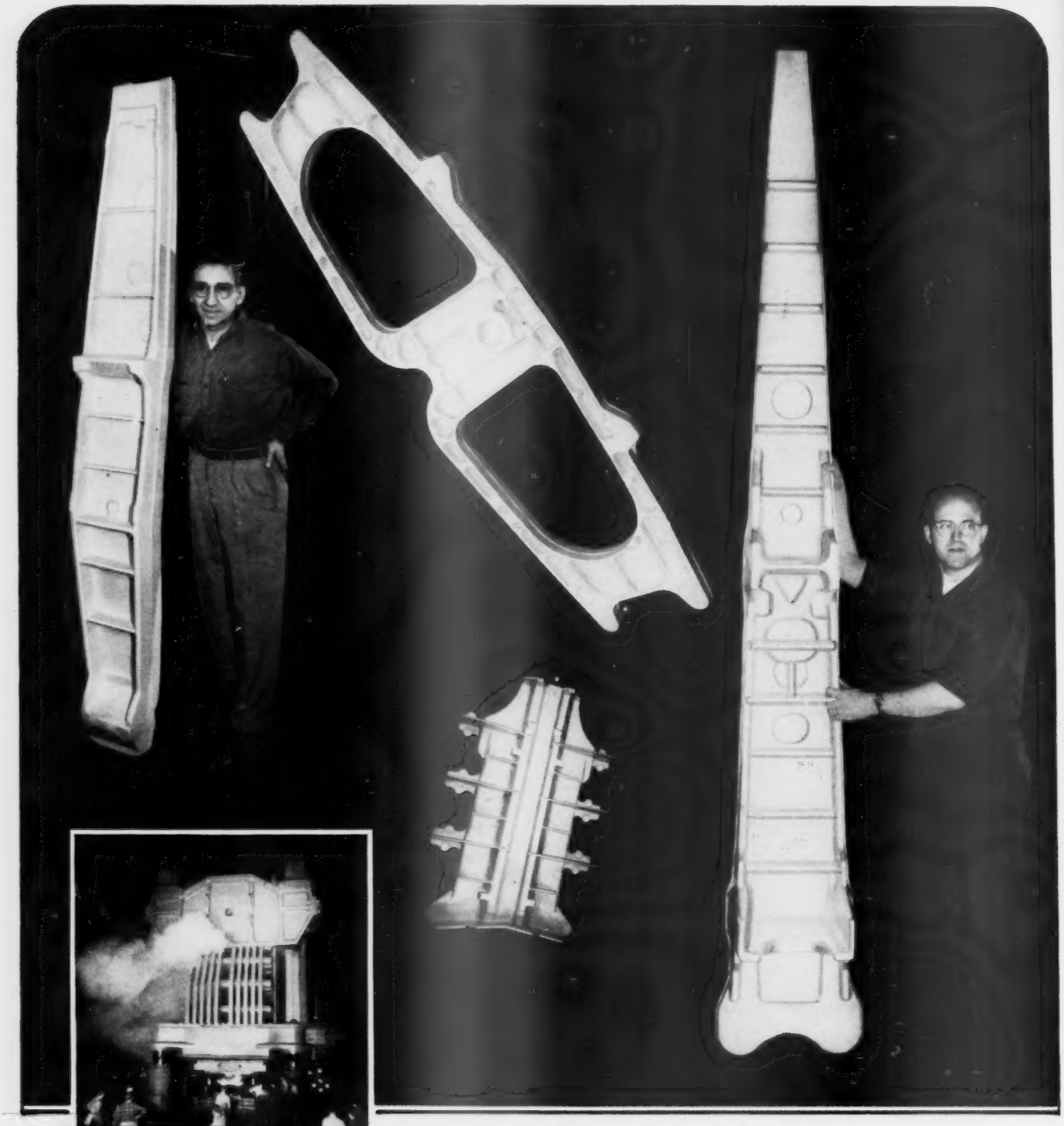

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Handbook of Noise Measurement. **General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.** *See page 6*

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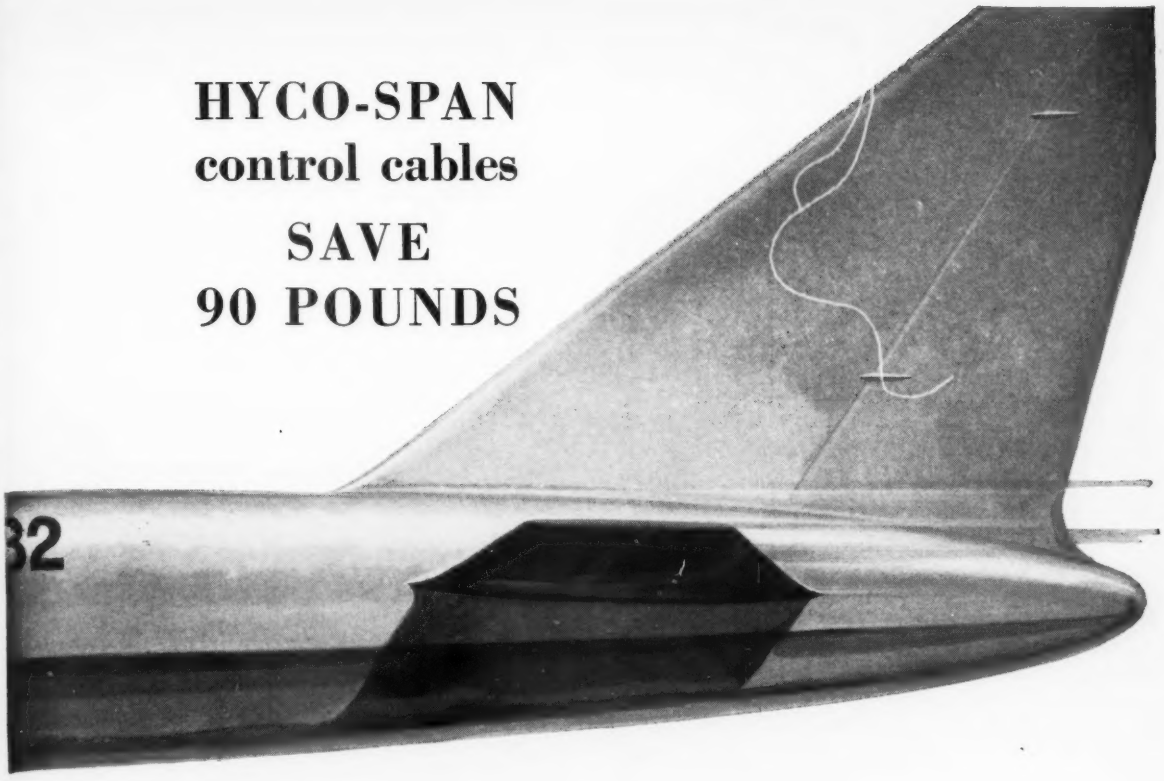

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As a result, you can eliminate as much as 90 pounds of useless dead weight by simplifying control cable installations.

Also: Hyco-Span Cables resist corrosion as well as stainless steel . . . operate safely on low cable tension . . . seldom require readjustment . . . are non-magnetic . . . do not affect the accuracy of sensitive instruments.

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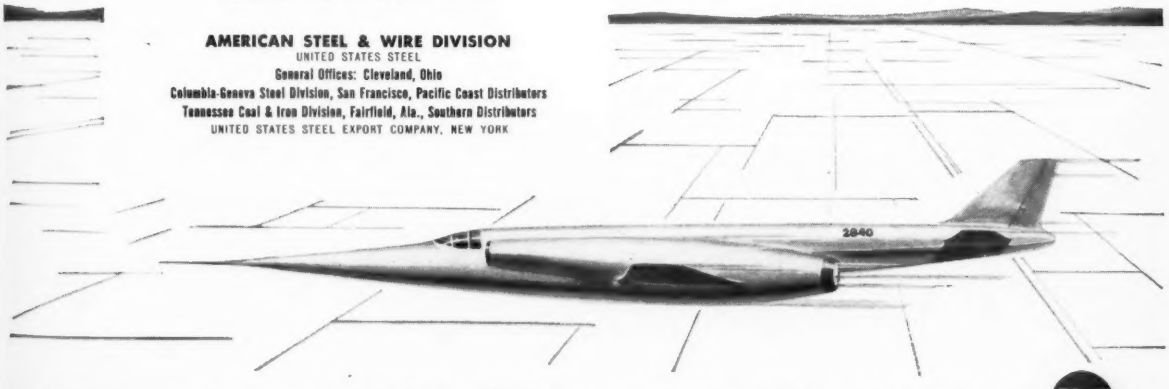

USS American HYCO-SPAN Aircraft Control Cables

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NUMBER 1 OF A SERIES

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